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NAVAL POSTGRADUATE SCHOOL
Monterey, California



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AN APPLICATION OF CP/CMS
TO THE TIME SERIES ANALYSIS

by

Young Woo Lee

March 1977

Thesis Advisor:

F. R. Richards

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An Application of CP/CMS
To The Time Series Analysis

by

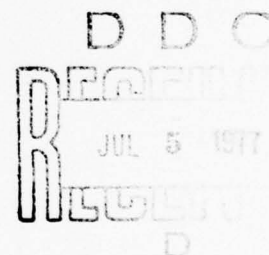
Young Woo Lee
Lieutenant Colonel, Republic of Korean Air Force
B.S., Korean Air Force Academy, 1963

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Author

Young Woo Lee

Approved by:

JR Richards

Thesis Advisor

W D Foreman

Second Reader

W D Foreman

Chairman, Department of Operations Research

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ABSTRACT

An interactive package of computer programs has been developed for the analysis of time series data. The package, called the Time Series Editor, is designed around the Box-Jenkins' statistical methodology of time series analysis. The Time Series Editor was developed for time-shared use on the Controlled Program/Cambridge Monitor System (CP/CMS) but could be easily modified to accommodate other time-sharing systems. The Time Series Editor assists in data preparation, entry, analysis and diagnostic testing. Utilization of the package requires only a limited knowledge of the computer system with all required user responses prompted by the Editor.

TABLE OF CONTENTS

I.	INTRODUCTION	9
II.	BOX-JENKINS METHODOLOGY	14
	A. PROPERTIES OF STATIONARY PROCESS	14
	B. AUTOREGRESSIVE-MOVING AVERAGE MODELS	16
	C. HOMOGENEOUS NONSTATIONARY SERIES	18
	D. SEASONAL TIME SERIES	19
	E. PARAMETER ESTIMATION	21
	F. DIAGNOSTIC CHECKING	22
	G. FORECASTING	23
III.	DESCRIPTION OF THE TIME SERIES EDITOR	27
	A. THE EXECUTIVE PROGRAM	27
	B. DATA ENTRY AND PROGRAM OUTPUT	28
	1. Offline Card Input	29
	2. Numeric Keyboard Input	31
	3. Alphabetic Keyboard Input	32
	C. PLOT PROGRAM	32
	D. DIFF PROGRAM	33
	E. AUTO PROGRAM	33
	F. ESTIMATE PROGRAM	34
	G. FORECAST PROGRAM	35
	H. SIMULATE AND GENERATE PROGRAMS	36
IV.	EXAMPLE TIME SERIES ANALYSIS	39
V.	SUMMARY AND RECOMMENDATIONS	44

APPENDIX A: User's Guide to Time Series Editor	- - - - -	-47
APPENDIX B: Sample User Session and Program Output	- - - - -	-52
APPENDIX C: Program Listings	- - - - -	-84
LIST OF REFERENCES	- - - - -	-110
INITIAL DISTRIBUTION LIST	- - - - -	-111

LIST OF FIGURES

Figure 1.	Box-Jenkins forecasting method - - - - -	10
Figure 2.	Card deck for OFFLINE READ - - - - -	30
Figure 3.	Plots of series C - - - - -	61
Figure 4.	Plots of autocorrelations of series C - - - - -	63
Figure 5.	Plots of partial autocorrelations of series C - - - - -	64
Figure 6.	Plots of autocorrelations of 1st differenced series C - - - - -	67
Figure 7.	Plots of partial autocorrelations of 1st differenced series C - - - - -	68
Figure 8.	Plots of the forecasted values adjoined to the original series C with 80% confidence limits about the forecasts - - - - -	81
Figure 9.	Plots of simulated series with model (1,1,0) of series C - - - - -	83

LIST OF TABLES

Table I.	Auto and partial autocorrelations of series C - - - - -	62
Table II.	Values of 1st differenced series C - - - - -	65
Table III.	Auto and partial autocorrelations of 1st differenced series C - - - - -	66
Table IV.	Values of simulations for model (1,1,0) of series C - - - - -	82

I. INTRODUCTION

Operations researchers, statisticians, economists, marketing personnel, managers and many others are frequently faced with the need to analyze time series data. In most cases their objective is to discover patterns or recognizable behavior in historical data that can be used to construct mathematical models of the time series from which forecasts of future behavior can be obtained. The importance of being able to forecast future behavior accurately cannot be overemphasized. Whether the data be budget expenditures, populations, natural resource consumption, prices, demands, economic indicators, stock-market prices, manpower levels or whatever, decision makers concerned with planning for the future must base their decisions on their best predictions about the future behavior of the time series.

Until the late 1960's, the analysis techniques were primarily those of spectral analysis with heavy application of harmonic analysis and mathematical transform theory. Because of the mathematical sophistication required by the spectral approach, the analysis capability resided fairly exclusively in the hands of mathematicians and engineers. Consequently, many naive forecasting methods such as moving averages, exponential smoothing and decomposition analyses were adopted by the majority of the decision makers. Since the late 1960's the statistical analysis of time series, embodied primarily

in the methodology developed by Box and Jenkins [Ref. 2], has received widespread acceptance. Because the Box-Jenkins approach is described in a vocabulary more familiar to operations researchers, statisticians, economists and managers, more and more business and government decision makers are building models from past data to use for planning into the future.

Many algorithms and computer programs for performing the analyses required by the Box-Jenkins approach have been developed and are readily available from many sources. One of the best sources is the collection of FORTRAN computer subroutines which resides in the International Mathematical and Statistical Library (IMSL) [Ref. 4]. The major problem with using the available computer resources lies not with any deficiency of the algorithms or the programs, but with the very nature of the Box-Jenkins approach. The Box-Jenkins method is an iterative approach which is described in Figure 1. [See Wheelwright and Makridakis, ref. 7.]

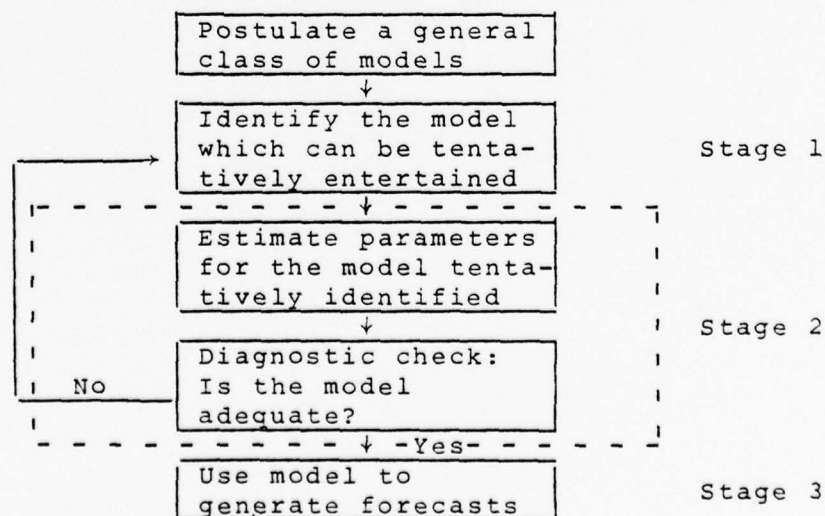


Figure 1. Box-Jenkins forecasting method.

Figure 1 shows that the Box-Jenkins method is a multi-stage, iterative process. It begins with the postulation of general class of models which has been found, experimentally to be extremely rich. Thereafter, the modeling procedure continues as a trial-and-error process with several decision points where the analyst is required to select the next direction based on the best information available to him. Each stage of the process outlined in Figure 1 may consist of several steps, and, even with the existing computer software resources, the modeling process is usually very time consuming. For example, a typical Box-Jenkins time series analyst using a batch processing computer system with access to the IMSL library of subroutines might perform the following sequence of tasks:

1. Prepare time series data.
2. Plot and visually examine the time series looking for nonstationarity, trends, deterministic patterns, etc.
3. Write a program to call the IMSL subroutine that calculates the mean, the variance, the autocorrelations and the partial autocorrelations.
4. Plot the autocorrelations and partial autocorrelations. This provides the major information needed for identification of the time series.
5. Write a program to call the IMSL subroutine which transforms the time series to adjust for seasonal patterns, nonstationary behavior or other behavior which deviates from that assumed by the class of models postulated.
6. Repeat steps 2) through 4) using the transformed data.
7. Review the statistical properties of the autocorrelations and partial autocorrelations for tentative identification of the model.

8. Write a program to call the IMSL program that estimates the model parameters and computes the residuals.
9. Write a program to perform goodness of fit tests.
10. Analyze the residuals following steps 1) through 9) just as was done with the original time series.
11. Refine the model using the information obtained by the analysis of the residuals.
12. Repeat steps 8) through 10).
13. When an adequate model is obtained, write a program to call the IMSL subroutine which forecasts and determines confidence intervals for future values of the time series.

Between each pair of steps the user must manually intervene and make a subjective decision based on the information available. Thus, a great deal of user interaction is required in order to determine a mathematical model and a forecast equation. Even with rapid computer turnaround time, the process can easily consume a day or more of calendar time.

This report describes an effort to alleviate some of the problems involved with modeling time series using the Box-Jenkins approach. An interactive computer package which provides easy user access to the computational computer subroutines available in IMSL and similar subroutine libraries was developed. The package, called the Time Series Editor, was written for time-shared use on the Naval Postgraduate School's Controlled Program/Cambridge Monitor System (CP/CMS). Since all programs except the executive routine are written in FORTRAN, the Time Series Editor could be easily modified to accommodate other time-sharing systems. The Time Series Editor assists the user in data preparation,

entry, model construction, diagnostic testing and forecasting. Utilization of the package requires only a limited knowledge of CP/CMS. In fact, with the User's Guide provided in this report, a complete Box-Jenkins time series analysis can be performed in a short time by even a naive computer user. For this reason, the Time Series Editor should be valuable as an instructional aid for laboratory use in a time series class.

A brief description of the Box-Jenkins methodology is given in Chapter 2 to serve as a point of reference for the remaining material. Chapter 3 contains descriptions of each of the programs contained in the Time Series Editor. The use of the Time Series Editor is illustrated with an example time series which is given in Chapter 4.

Chapter 5 contains a summary and recommendations for additions to the Time Series Editor. A User's Guide which includes an explanation of CP/CMS sufficient for utilization of the Time Series Editor is given in Appendix A. Sample user sessions, sample outputs and complete computer listings are also included in appendices.

II. BOX-JENKINS METHODOLOGY

In this chapter a brief description of the Box-Jenkins time series modeling methodology is given. For a more detailed discussion the reader is referred to the texts by Anderson [Ref. 1], Box and Jenkins [Ref. 2], Pindyck and Rubinfeld [Ref. 6], and Nelson [Ref. 5]. The material presented here is included primarily to serve as a point of reference for the program descriptions that follow in later chapters. It is also included here to aid the user in understanding the computer output and the questions asked by the Time Series Editor.

A. PROPERTIES OF STATIONARY PROCESSES

A discrete stochastic time series is a set of observations y_1, y_2, \dots, y_T generated sequentially in time by a set of jointly distributed random variables; i.e., the data y_1, \dots, y_T represents a particular realization of a joint probability distribution $f(y_1, y_2, \dots, y_T)$. A future observation, y_{T+k} can be thought of as being generated by a conditional probability distribution function $f(y_{T+k} | y_1, \dots, y_T)$ given the realization through time T . The stochastic process which generates the time series is said to be stationary if its properties are unaffected by a change of time origin; that is, if the joint probability distribution associated with m observations $y_{t_1}, y_{t_2}, \dots, y_{t_m}$, made at any

set of times t_1, t_2, \dots, t_m is the same as that distribution associated with m observations $y_{t_1+k}, y_{t_2+k}, \dots, y_{t_m+k}$ made at times t_1+k, \dots, t_m+k .

If a process is stationary, the probability distribution $f(y_t)$ is the same for all times t . Thus the process has a constant mean

$$\mu = E[y_t] = \int_{-\infty}^{\infty} y f(y) dy$$

which defines the level about which it fluctuates, and a constant variance

$$\sigma^2 = E[(y_t - \mu)^2] = \int_{-\infty}^{\infty} (y - \mu)^2 f(y) dy$$

which measures its variability about the mean level. Since the probability distribution $f(y_t)$ is the same for all times t , the mean and the variance can be estimated by the averages taken over time:

$$\bar{y} = \frac{1}{N} \sum_{t=1}^N y_t \quad \text{and} \quad \hat{\sigma}^2 = \frac{1}{N} \sum_{t=1}^N (y_t - \bar{y})^2$$

The stationarity assumption also implies that the bivariate distribution $f(y_{t_1}, y_{t_2})$ is the same for all times t_1 and t_2 such that $|t_2 - t_1|$ is constant. The autocorrelation at lag k , ρ_k , is defined as:

$$\rho_k = \frac{E[(y_t - \mu)(y_{t+k} - \mu)]}{\sigma^2}$$

This is estimated by the time average:

$$r_k = \left(\frac{1}{N} \sum_{t=1}^{N-k} (y_t - \bar{y})(y_{t+k} - \bar{y}) \right) / \hat{\sigma}^2$$

The plot of the autocorrelation function vs. the lag k , called the correlogram, is very useful for the purpose of determining if a process is stationary and for identifying the appropriate model.

Another function which is important for purposes of identifying the appropriate linear time series model is the partial autocorrelation function. Let $\hat{y}_t = b_0 + b_1 y_{t+1} + b_2 y_{t+2} + \dots + b_{k-1} y_{t+k-1}$ where the b 's are the least squares estimates of the linear regression coefficients (β 's) in the model

$$y_t = \beta_0 + \beta_1 y_{t+1} + \dots + \beta_{k-1} y_{t+k-1} + e_t.$$

Let z_t be the residual of y_t after removing the linear effect of $y_{t+1}, \dots, y_{t+k-1}$ from y_t ; i.e.

$$z_t = y_t - \hat{y}_t.$$

The partial autocorrelation of lag k , denoted ϕ_{kk} , is defined to be the simple correlation of lag k for the adjusted series z_1, z_2, \dots .

B. AUTOREGRESSIVE-MOVING AVERAGE MODELS

The general class of models postulated by Box and Jenkins for stationary time series is the class of linear models defined by:

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \theta_0 a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \quad (1)$$

where $\{a_t\}$ is a sequence of observations from a white noise process ($E[a_t] = 0$, $\text{var}[a_t] = \sigma_a^2$ and $E[a_t a_{t+k}] = 0$ for all $k > 0$) and $\phi_1, \dots, \phi_p, \theta_0, \theta_1, \dots, \theta_q$ are $p+q+1$ parameters that are to be estimated from the data. The model above is called a mixed autoregressive-moving average (ARMA) model of order (p, q) . If $q=0$, the model is called an autoregressive model of order p , AR_p ; and if $p=0$, the model is called a moving average model of order q , MA_q . Thus, the general linear model of Box-Jenkins represents the current observation y_t as a weighted sum of past observations and present and past random shock terms. The model is usually expressed in abbreviated form using operator and transfer function notation:

$$\phi(B)y_t = \theta_0 + \Theta(B)a_t \quad (2)$$

where $\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p$, $\Theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$ and B is the operator defined by $B^k y_t = y_{t-k}$. In order to guarantee stationarity it is necessary that the autoregressive parameters satisfy certain conditions. The conditions can be summarized by stating that all roots of the polynomial equation $\phi(B) = 0$ (treating B as a dummy variable) must lie outside the unit circle.

The tentative identification of the appropriate member of the general class (the identification of p and q) is accomplished by comparing the sample autocorrelation and partial autocorrelation functions of the given time series with the theoretical autocorrelation and partial autocorrelation functions of members of the general linear class. For most

stationary time series an adequate fit can be found in a model with p and q relatively small, say three or less.

C. HOMOGENEOUS NONSTATIONARY SERIES

In many cases the time series of interest is not stationary. Instead, the probabilistic structure of the process which generates the time series may change with time. For example, there may be some sort of trend or seasonal pattern in the time series. If the process does, nevertheless, exhibit behavior which is somewhat homogeneous then the original time series can often be transformed into a stationary series that can be described by an ARMA model.

A time series is said to be homogeneous nonstationary of order d if $w_t = \Delta^d y_t$ is a stationary series. Here Δ denotes the differencing operator:

$$\Delta y_t = y_t - y_{t-1} = (1-B)y_t$$

$$\Delta^k y_t = \Delta(\Delta^{k-1} y_t)$$

That a time series is nonstationary is indicated by a plot of the time series itself (e.g. a nonconstant mean) and by the autocorrelation function. Characteristic of the correlogram of a nonstationary series is the very slow damping out of the autocorrelation. When this property of the correlogram is observed, the user should difference the series one time and compute the correlogram for the series $w_t = \Delta y_t$. The user should continue to difference the series until the resulting series appears stationary or until the procedure

appears not to improve the series. The transformed series $w_t = \Delta^d z_t$ is then modeled as an ARMA model. The resulting model, in terms of the original time series is:

$$\phi(B)\nabla^d y_t = \theta_0 + \theta(B)a_t. \quad (3)$$

In this form of the model, the transfer function $\phi(B)$ is assumed to be stationary; i.e., all roots of $\phi(B) = 0$ are outside the unit circle. It is sometimes written in the equivalent form

$$\psi(B)y_t = \theta_0 + \theta(B)a_t \quad (4)$$

where $\psi(B) = \phi(B)\nabla^d = \phi(B)(1-B)^d$ and, clearly, $\psi(B)$ is not a transfer function of a stationary series ($\psi(B) = 0$ has d roots on the unit circle). The ARMA model for the differenced series is called an autoregressive integrated moving average (ARIMA) model of order (p,d,q) . For the purpose of distinguishing between the two forms of the ARIMA model, equation (3) is referred to as the differenced form and (4) as the undifferenced form.

D. SEASONAL TIME SERIES

Seasonality is defined as cyclical behavior that occurs on a regular calendar basis. For example, a highly seasonal time series would be the sales of Christmas ornaments which exhibit a strong peak every December. Rainfall, crop yields, livestock production, energy consumption, and many other time series that are influenced by the weather all exhibit

seasonal patterns. Seasonal patterns are often easy to spot simply by observing the time series directly. However, many times, if the variability in the time series is large, seasonal patterns will not be distinguishable from the other fluctuations. Recognition of seasonality is important since it provides information that can aid in modeling and forecasting. The autocorrelation function makes recognition of seasonal patterns easier.

Suppose, for example, that a monthly series has an annual seasonal pattern. Then the realizations should show some special correlation with other realizations which lead or lag by 12 months; i.e., there should be some correlation between y_t and y_{t+12} , y_t and y_{t+24} , y_t and y_{t+36} , etc. These correlations should manifest themselves in the autocorrelation function which should show peaks at $k = 12, 24, 36$, etc.

The Box-Jenkins modeling approach for seasonal (nonstationary) time series is to first transform the seasonal series to a new series which is stationary. This can often be accomplished by taking seasonal differences $\Delta_s^d y_t$ defined as follows:

$$\begin{aligned}\Delta_s y_t &= y_t - y_{t-s} = (1-B^s)y_t \\ \Delta_s^d y_t &= \Delta_s (\Delta_s^{d-1} y_t) = (1-B^s)^d y_t\end{aligned}$$

The transformed time series $\{w_t\}$ ($w_t = \Delta_s^d y_t$) is then analyzed as a stationary time series. (It may be necessary to perform more than one seasonal and/or differencing transformation before the resulting series is stationary.) Suppose that

the resulting ARMA model for the transformed series is

$$\phi(B)w_t = \theta_0 + \theta(B)a_t$$

The model for the original series is then

$$\phi(B)(1-B^s)^d y_t = \theta_0 + \theta(B)a_t.$$

E. PARAMETER ESTIMATION

Suppose the series has been tentatively identified as an ARIMA (p,d,q) model:

$$\phi(B)\Delta^d y_t = \theta_0 + \theta(B)a_t \quad (5)$$

where $\phi(B) = 1 - \phi_1 B - \dots - \phi_p B^p$ and $\theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$. There are $p+q+2$ unknown parameters, $\{\phi_1, \dots, \phi_p, \theta_0, \theta_1, \dots, \theta_q, \sigma_a^2\}$, that must be estimated. The Box-Jenkins procedure separates the estimation problem into two parts. First estimates are obtained for the autoregressive-moving average parameters $\underline{\phi}$ and $\underline{\theta}$, and the estimates are then made of σ_a^2 and θ_0 which are functions of the ARMA parameters. The usual procedure is to select those parameter values $\hat{\underline{\phi}}$ and $\hat{\underline{\theta}}$ that minimize the sum of squared errors. Let $\mu_w = \theta_0 / (1 - \phi_1 - \dots - \phi_p)$ and $\tilde{w}_t = \Delta^d y_t - \mu_w$. Then, it can be easily shown that $\mu_w = E[w_t]$ and that (5) can be rewritten as:

$$\phi(B)(w_t - \mu_w) = \theta(B)a_t$$

or

$$a_t = \theta^{-1}(B)\phi(B)(w_t - \mu_w)$$

Let \bar{w} , the sample mean, be the estimate of μ_w (if $d > 0$, μ_w is usually 0) and let

$$\hat{a}_t = \hat{\theta}^{-1}(B) \phi(B) (w_t - \bar{w}) . \quad (6)$$

Let
$$S(\hat{\phi}, \hat{\theta}) = \sum_t \hat{a}_t^2 .$$

The objective is to select those parameters $\hat{\phi}$ and $\hat{\theta}$ that minimize $S(\hat{\phi}, \hat{\theta})$. Since the equation S is nonlinear in the parameters, iterative search methods must usually be used in the minimization. An estimate of σ_a^2 is provided by

$$\hat{\sigma}_a^2 = S(\hat{\phi}, \hat{\theta}) / n - p - q$$

F. DIAGNOSTIC CHECKING

After the model has been tentatively identified and parameter estimates have been obtained, the next task is to test whether or not the original specification was correct and the model is adequate. The process of testing the model takes many forms, but usually involves at least the following two steps:

1. Generate a simulated series from the estimated model and compare the simulated series and its autocorrelation functions with the original series and its respective autocorrelation and partial autocorrelation functions. The comparison is primarily subjective.

2. Compute the residuals of the estimated model from (6) and compare the properties of the residuals with those assumed for the shock terms of the actual process. The residuals should be normally distributed and uncorrelated with each other. There are many quantitative statistical tests that can be used to test hypotheses about normality and zero correlation.

A plot of the autocorrelation and partial autocorrelation functions of the residuals provides not only a test of whether or not the residuals are uncorrelated, but, if they are correlated, the plots suggest modifications to the model. For example, suppose the model was tentatively specified as the ARMA(1,1) model: $(1-0.5B)(y_t-2) = (1+0.7B)a_t$ and the autocorrelations and partial autocorrelations of the residuals suggest the model

$$(1-0.3B)a_t = u_t$$

where the u 's are white noise (uncorrelated with variance σ_u^2). Then, the next model entertained for the original time series should be the ARMA(2,1) model:

$$(1-0.3B)(1-0.5B)(y_t-2) = (1+0.7B)u_t .$$

G. FORECASTING

The objective of forecasting is to predict future values with as little error as possible. The criterion most often used for selection of the best forecast is that forecast which has minimum mean square forecast error. Thus, if

$\hat{y}_T(\ell)$ represents the forecast at origin T of the value $y_{T+\ell}$, the objective is to select $\hat{y}_T(\ell)$ so that

$$E[(y_{T+\ell} - \hat{y}_T(\ell))^2]$$

is minimized. This forecast is given by taking $\hat{y}_T(\ell)$ as the conditional expectation of $y_{T+\ell}$:

$$\hat{y}_T(\ell) = E[y_{T+\ell} | y_T, y_{T-1}, \dots, y_1] \quad (7)$$

The forecasts can be easily generated recursively from the mathematical model utilizing the fact that

$$E[y_{T-j}] = y_{T-j} \quad \text{for } j=0,1,2 \text{ (T is current time)}$$

and

$$E[a_t] = \begin{cases} 0 & \text{if } t > T \\ a_t & \text{if } t \leq T \end{cases} .$$

For example, suppose the estimated model is:

$$(1 - 0.5B + 0.6B^2)y_t = (1 + 0.3B)a_t$$

or, equivalently,

$$y_t = 0.5y_{t-1} - 0.6y_{t-2} + a_t + 0.3a_{t-1}$$

where $y_{100} = 1.4$, $y_{99} = 1.0$, and $a_{100} = 0.2$. The forecasts of y_{101} , y_{102} , and y_{103} made at time $t = 100$ are found as follows:

$$\begin{aligned}\hat{y}_{100}(1) &= E[y_{101} | y_{100}, y_{99}, \dots, y_1] \\ &= E[0.5y_{100} - 0.6y_{99} + a_{101} + 0.3a_{100}] \\ &= 0.5y_{100} - 0.6y_{99} + 0.3a_{100}\end{aligned}$$

$$\hat{y}_{100}(1) = 0.16$$

$$\begin{aligned}\hat{y}_{100}(2) &= E[y_{102} | y_{101}, y_{100}, \dots, y_1] \\ &= E[0.5y_{101} - 0.6y_{100} + a_{102} + 0.3a_{101}] \\ &= 0.5\hat{y}_{100}(1) - 0.6y_{100}\end{aligned}$$

$$\hat{y}_{100}(2) = -0.76$$

$$\begin{aligned}\hat{y}_{100}(3) &= E[0.5y_{102} - 0.6y_{101} + a_{103} + 0.3a_{102}] \\ &= 0.5\hat{y}_{100}(2) - 0.6\hat{y}_{100}(1) \\ &= -0.48\end{aligned}$$

Let $e_T(\ell) = y_{T+\ell} - \hat{y}_T(\ell)$ be the forecast error ℓ periods ahead. It can be shown that $e_T(\ell)$ is given by

$$e_T(\ell) = a_{T+\ell} + \psi_1 a_{T+\ell-1} + \dots + \psi_{\ell-1} a_{T+1} \quad (8)$$

where the weights ψ_j are determined from

$$\psi(B) = \phi^{-1}(B) (1-B)^{-d} \theta(B) .$$

The variance of the forecast error is given by

$$E[e_T^2(\ell)] = (1 + \psi_1^2 + \dots + \psi_{\ell-1}^2) \sigma_a^2 \quad (9)$$

From this, a confidence interval of z standard deviations around a forecast ℓ periods ahead would be given by

$$C_z(\hat{y}_T(\ell)) = \hat{y}_T(\ell) \pm z(1 + \sum_{j=1}^{\ell-1} \psi_j^2)^{1/2} \hat{\sigma}_a \quad (10)$$

Note from expression (8) that the one-step ahead forecast error, $e_T(1)$, is simply a_{T+1} , i.e.

$$y_{T+1} - \hat{y}_T(1) = a_{T+1} .$$

This explains the common use of the word residual to refer to the random shock terms. Also, from expressions (9) and (10) it is clear that the forecast error variance is a non-decreasing function of the length of the forecast period ℓ . Thus, the confidence bands must get wider as the forecast period gets larger.

III. DESCRIPTION OF THE TIME SERIES EDITOR

In this chapter, descriptions are given of each program in the Time Series Editor that interacts with the user. There are eight separate program modules that are currently included in the Editor. In addition, there are a few other programs that reside in the Editor, but which are completely transparent to the user. The latter programs serve useful functions in conjunction with the other eight modules, but they are not described here.

No attempt is made to describe the actual mathematical calculations or algorithms that are performed by the programs. Rather, the objective is to give general descriptions about what each program can do for the user and how the user interacts with the programs. The eight programs described in this chapter are TIMESER EXEC, PLOT, DIFF, AUTO, ESTIMATE, FORECAST, SIMULATE and GENERATE.

A. THE EXECUTIVE PROGRAM

The Time Series Editor contains a master program, called TIMESER EXEC, that provides file control of all of the other programs, controls input and output, takes care of the necessary CP/CMS protocol and provides instructions to the user as to what is in the Time Series Editor and how each program can be used. TIMESER is written in a special CP/CMS Exec language. It is the only program in the Editor that is not

written in FORTRAN, and, consequently, it should be the only program that would need modification if the Editor were to be adapted to another time sharing system.

After the user has logged into CP/CMS and linked to the files containing the Time Series Editor (a user's guide for this is given in Appendix A) the entire Editor package is made available to the user by his command, TIMESER EXEC.¹ On entry of this command, the EXEC provides a guided tour through the Editor. It tells the user what the Editor can provide; it asks the user what tasks he wants to do; and, on the basis of the user's answers, it instructs the user as to what data is required and how it must be entered. When the user selects an option for execution, the EXEC loads the appropriate program(s) and automatically manipulates any required input and output files.

B. DATA ENTRY AND PROGRAM OUTPUT

Whenever data is required, the user is prompted by either the EXEC or the program module being executed. In most cases, the necessary user response is a single alphanumeric character input during execution by keyboard. However, in some cases, the amount of data required is too bulky for keyboard entry, and the data is entered more efficiently offline via cards or tapes. Similarly, most of the output is typed out

¹There is a second executive routine, called TS EXEC, that can be used by the more experienced analysts who wish to suppress some of the user instructions. This abbreviated program provides the same basic services as TIMESER EXEC.

right at the user's terminal, but, in some cases, the output is printed offline for conservation of time and to provide a hard copy of the results.

Detailed descriptions are given of the input and output requirements of each program in the individual program write-ups. However, there are some general principles of data input that apply for all programs. These are described in this section.

1. Offline Card Input

When a large volume of data, such as a time series of a hundred or more observations, is required, the data can be entered more efficiently through mechanisms other than keyboard entry. Keyboard entry would be not only much slower, but also more likely to contain errors than other input mediums. Thus, the Time Series Editor requires that the time series data be entered offline via cards. The data are read offline and stored in the user's file FT02F001 which is read automatically when required by the Time Series Editor. An example of an input data deck for use in the Editor is shown in Figure 2.

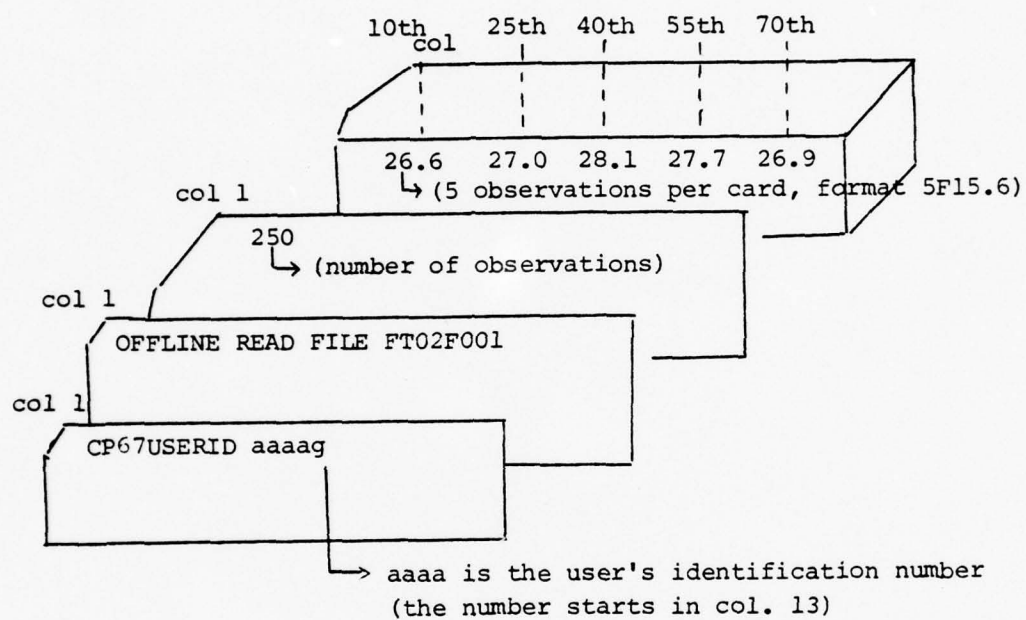


Figure 2. Card deck for offline read.

2. Numeric Keyboard Input

When the user is prompted to enter numerical values such as the number of observations, the number of parameters, parameter estimates or starting conditions, he must enter those values before program execution can continue. The user should enter the data according to standard FORTRAN practice. That is, integer data should be entered (without decimal) for counts and names beginning with the letters I through N; floating data should be entered with decimal point for all other variables. Because a typed decimal point overrides a floating format it is not necessary for the user to concern himself with the format for floating data (the user is never asked to enter more than a single observation on a line). However, some care must be exercised when entering integer data because integer data must be right justified in its format field. The user is told whenever the integer format is anything other than I1. For example, suppose the user wants to analyze a time series having only 65 observations. If the program that he is executing requires the length of the time series, the user will receive the following request:

ENTER LENGTH OF THE TIME SERIES, L, VIA I3.

The user should then enter:

```
col.   123
      b65  (b represents a blank space)
```

If the blank were omitted, the program would read the length as 650 and many problems would occur.

3. Alphabetic Keyboard Input

The Time Series Editor often requests the user to respond with alphabetic input. For example, it may ask him a question that requires a yes or no answer, or it may ask him what option he wants to execute. The editor has been programmed to read only the first letter of the user's response. Thus, he need only enter a single letter for each such inquiry. For example, he should enter Y for yes, N for no, P for the PLOT option, E for the ESTIMATE option, etc.

4. Output

Most of the results are written out right at the user's terminal. In some cases, however, the output is printed offline to conserve time. Such results as plots and transformed time series are written onto various files (FT03F001, FT08F001, FT01F001) and the EXEC program prints them offline under the user's identification number. The files can also be printed out at the user's terminal at his request.

C. PLOT PROGRAM

The PLOT program plots any given time series which resides in file FT02F001. Other than the time series, which is entered offline, the program requires only that an identification title for the plot be entered by the user during execution. The plot is automatically printed offline and is also found in file FT08F001. The PLOT program uses the subroutine PLOTP in the IBM Scientific Subroutine Package Library (SSPLIB).

D. DIFF PROGRAM

The DIFF program performs seasonal and/or nonseasonal differences and it allows the user to transform a given time series using logarithmic or exponential transformations. The program requires the given time series to reside in file FT02F001, and it requires the user to input the following information during program execution:

- (1) Type of time series (seasonal, nonseasonal)
- (2) Order of differencing (for stationarity)
- (3) Length of seasonal period (for seasonal series only)
- (4) Type of transformation (none, exponential, logarithmic)
- (5) Transform parameters (if log or exponential transform is desired)
- (6) Yes or no responses to questions about plotting of autocorrelations and partial autocorrelations of transformed/differenced series.

The transformed/differenced series is written out into file FT03F001 and can be printed out at the user's terminal if he requests a printout. Plots of the transformed/differenced series, its autocorrelations, and its partial autocorrelations can be printed offline.

This program is used to transform a given series that may be seasonal and/or nonstationary or nonhomogeneous into a stationary series of the type possible for analysis using the Box-Jenkins methodology. The program utilizes the IMSL subroutine, FTRDIF.

E. AUTO PROGRAM

AUTO calculates summary statistics from a given time series. The summary statistics include the sample mean,

variance, autocorrelations, and partial autocorrelations of logs one through 20. All of the statistics are printed out at the user's terminal, and, in addition, plots of the autocorrelations and partial autocorrelations are printed out offline. Furthermore, the plots reside in the user's file FT08F001 so that they may also be printed at the user's terminal. That is, however, a very time consuming process. AUTO provides the major information about stationarity, seasonality and model identification. With the Box-Jenkins procedure, the second moments (autocorrelations and partial autocorrelations) are the primary tools for tentative model identification. In addition, AUTO is used in the diagnostic checkout phase of model building to test the residuals.

The time series (original, transformed or differenced, or residuals) must reside in file FT02F001. (When a series is transformed or the residuals are calculated, those values are automatically stored in file FT02F001 temporarily for further analysis.) The program uses the IMSL subroutine FTAUTO.

F. ESTIMATE PROGRAM

After the user has tentatively identified a model, the Editor program ESTIMATE should be executed to calculate maximum likelihood estimates of the model parameters. It estimates the autoregressive parameters, the moving average parameters, the constant term and the variance of the shock terms. It also determines the residuals which are so important for the diagnostic checkout phase of model building.

ESTIMATE uses the IMSL subroutine FTMAXL to estimate the parameters.

ESTIMATE needs the time series in file FT02F001 prior to execution. During program execution the user will be prompted with the following requests:

- 1) Enter number of autoregressive (AR) parameters.
- 2) Enter number of moving average (MA) parameters.
- 3) Enter the number of differences.

ESTIMATE then provides the following output:

- 1) Estimated AR parameters for the undifferenced form of the model.
- 2) Estimated MA parameters.
- 3) Estimated overall MA constant and white noise variance.
- 4) Auto- and partial correlations of residuals.
- 5) Plots of (4).
- 6) Values of residuals printed out offline and residuals stored in file FT03F001.
- 7) Chi-square goodness of fit value for estimated model.

G. FORECAST PROGRAM

The Editor program, FORECAST, uses the estimated mathematical model to compute forecasts of future values of the time series. It also computes $(1-\alpha)$ 100% probability limits for the forecasted values. The program utilizes the IMSL subroutine FTCAST.

The time series must reside in file FT02F001 before execution begins. During execution, the user is required to enter the following inputs:

- 1) Origin of forecasts
- 2) Number of AR parameters
- 3) Estimated values of AR parameters
- 4) Number of MA parameters
- 5) Estimated values of MA parameters
- 6) Overall MA constant and white noise variance
- 7) Maximum lead time for a forecast
- 8) Order of differencing in model
- 9) Significance level for forecast confidence limits

The program then provides the following output:

- 1) AR parameters in undifferenced form²
- 2) Forecasts for lead times $\ell = 1, 2, \dots, \max$
- 3) Deviations from each forecast for the $(1-\alpha)$ 100% confidence limits
- 4) Plots of forecasts and corresponding deviations joined with the original time series. This is plotted offline.

H. SIMULATE AND GENERATE PROGRAMS

Because of their similarities the Editor programs SIMULATE and GENERATE are described together. GENERATE allows the user to generate a time series from any ARIMA model that he specifies. The user must identify the model and give values for its parameters and starting conditions. The program takes the specified model, generates random noise terms, and calculates as many values of the time series as desired.

²Suppose the identified model was ARIMA (1,1,0). The differenced form is $(1-\phi_1 B)\Delta y_t = \theta_0 + a_t$. The undifferenced form is $(1-(1+\phi_1)B+\phi_1 B^2)y_t = \theta_0 + a_t$, found by multiplying $(1-\phi_1 B)$ by $(1-B)$.

This program is useful for purposes of classroom instruction for the generation of a wide variety of time series examples for model identification. It is also useful for the diagnostic phase of model checkout. A time series can be generated from the estimated model and its properties can be compared with those of the original series. If large discrepancies occur the estimated model may be inadequate.

The program requires the user to enter the following inputs during execution:

- 1) A random number seed
- 2) Number of AR parameters (undifferenced form)
- 3) Number of MA parameters
- 4) Length of time series
- 5) White noise variance
- 6) Values of AR and MA parameters
- 7) Initial starting values

The program output is the generated time series.

The SIMULATE program provides the capability of generating any number of simulated time series'. This is useful for predicting what might happen in the future and to demonstrate that, even within a given model, the actual observed time series' can differ substantially. This program uses GENERATE but also requires as input the number of simulated series the user wishes to generate. Furthermore, the SIMULATE program allows the user to select values of the original time series as starting values for the simulated series'. Output consists of the simulated series' and plots.

This completes the descriptions of the programs contained in the Time Series Editor. The actual program listings are given in Appendix C and sample user sessions are shown in Appendix B. In the next chapter, an example is given of an entire time series analysis from plotting to diagnostic testing and forecasting.

IV. EXAMPLE TIME SERIES ANALYSIS

In this chapter a description is given of a complete analysis of a time series using the Box-Jenkins procedure and the Time Series Editor. The time series analyzed is series C (Chemical Process Temperature Readings) from Box and Jenkins [Ref. 2, p. 528]. This time series was selected because it is analyzed completely in Ref. 2 so that the user can compare the results found there with the results given by the Time Series Editor.

The first step in the analysis of series C is to plot the time series. This is shown in Figure 3. The plot reveals rather wide fluctuations in the series but not the sort of explosive nonstationary behavior that would render a modeling attempt fruitless. The plot also reveals that the time series has a large amount of momentum (movements of the series tend to resist changes of direction). This is characteristic of ARIMA models with one or two differences.

Second, the autocorrelations, partial autocorrelations, mean, and variance of the series were estimated using AUTO. The numerical values are printed out in Table I and plots of the autocorrelations and partial autocorrelations are given in Figures 4 and 5. Figure 4 shows that the autocorrelations dampen out slowly in a near linear fashion. This is an indication that the series is nonstationary and that

one or more differences are needed to make it stationary. The partial autocorrelation plot is not informative when the autocorrelations fail to dampen out rapidly.

As suggested by the plots of original series and its autocorrelations, the program DIFF was executed to transform the series $\{y_t\}$ to the series $\{w_t\}$ where $w_t = \Delta y_t = y_t - y_{t-1}$. The values of the series $\{w_t\}$ are tabulated in Table II. The autocorrelations and the partial autocorrelations of the differenced series were then calculated and plotted. The values are given in Table III and the correlation plots are shown in Figures 6 and 7. The correlation plots suggest that the first differenced series is either ARMA(1,0) with the AR parameter near unity (the autocorrelations of the first differences also dampen out slowly) or a second difference is required. Thus, two candidates are suggested:

$$1) \text{ ARIMA}(1,1,0): (1-\phi_1 B)(1-B)y_t = \theta_0 + a_t$$

$$\text{and } 2) \text{ ARIMA}(0,2,0): (1-B)^2 y_t = \theta_0 + a_t.$$

For purposes of estimation, the second model was extended to include two moving average terms. Such "overfitting" is often done to see if the estimated moving average parameters turn out to be near zero, thus confirming the tentative identification. Thus, the two models entertained were:

$$1) (1-\phi_1 B)\Delta y_t = \theta_0 + a_t \quad \text{ARIMA}(1,1,0)$$

$$\text{and } 2) \Delta^2 y_t = \theta_0 + (1-\theta_1 B - \theta_2 B^2)a_t \quad \text{ARIMA}(0,2,2)$$

The next step is to calculate maximum likelihood estimates of the model parameters. The program ESTIMATE was

used to do this. The estimated parameters for the ARIMA (1,1,0) are:

$$\begin{aligned}\hat{\phi}_1 &= 0.8131 \\ \hat{\theta}_0 &= 0.0 \\ \hat{\sigma}_a^2 &= 0.0178396\end{aligned}$$

The autocorrelation and partial autocorrelations of the residuals were calculated and plotted to test the model. The correlations should appear to be estimates of a pure white noise process if the model is adequate. The model passed that test. A goodness-of-fit test was also performed to test the model. The chi-square value was $\chi^2 = 21.51$ with 19 df and a significance level of 0.3082. Thus, there is no strong evidence to suggest that the (1,1,0) model:

$$(1 - 1.8131B + 0.8131B^2)y_t = a_t \quad (11)$$

is inadequate.

Parameter estimates were also obtained for the ARIMA (0,2,2) model using ESTIMATE. The parameter estimates were:

$$\begin{aligned}\hat{\theta}_0 &= 0.0 \\ \hat{\theta}_1 &= 0.1382 \\ \hat{\theta}_2 &= 0.1300 \\ \hat{\sigma}_a^2 &= 0.0189515\end{aligned}$$

As before, the correlation plots of the residuals fail to suggest any inadequacy of the model. However, the chi-square lack of fit test yielded:

$$\chi^2 = 28.74 \text{ with 18 df and a significance level of 0.0516.}$$

Thus, if the ARIMA(0,2,2) model were the correct model a chi-square value as large as 28.74 would occur by chance with a probability of only 0.0516. There is some ground here for questioning the ARIMA(0,2,2) model. Because of its simplicity (parsimony is a very desirable feature for all models) and its better fit, the ARIMA(1,1,0) model, equation (11), was selected.

The estimated model, equation (11), for series C was used to calculate forecasts and confidence limits for those forecasts. The forecasts were made for 13 periods into the future at origin $t=20$ using the observed values of the original time series as starting conditions. Figure 8 shows a plot of the forecasted values adjoined to the original series with 80% confidence limits about those forecasts. The forecasted values and the probability deviations are tabulated on page 59. The plot shows that the confidence limits are very wide for lags far into the future.

Finally, program SIMULATE was utilized to generate two simulated series from eq. (11). Values of these two simulations are given in Table IV. Plots of those simulated series are shown in Figure 9. The general shape of those curves is like that of the original time series, thus confirming the estimated model.

The keyboard printout of the user session that generated the analysis above is included in Appendix B. The entire session lasted approximately one and a half clock hours including checkout of plots and consumed less than one minute of CPU time.

V. SUMMARY AND RECOMMENDATIONS

There is a growing need for an efficient unified collection of computer programs for aiding operations researchers, statisticians, economists, managers, and other people who must analyze time series. The Box-Jenkins methodology has opened the doors of time series analysis to an expanding population of analysts. Many computational algorithms have been developed and are available in many forms. The problem has been the iterative nature of the Box-Jenkins' model building procedure. Such a procedure is straightforward but can be very time consuming. The Time Series Editor that has been described in this report provides a unified collection of computer programs in an interactive time-sharing mode that can aid the user in all phases of the model building procedure from the plotting of the time series to the forecasting of future values. The Editor does not develop new computational algorithms. Rather, it makes those that are available easier and faster to use. With its simple input requirements which are all prompted by written instructions, the Editor can easily be used by the most naive computer user.

The Box-Jenkins methodology has been described in Chapter 2 and descriptions of the modules of the Time Series Editor have been given in Chapter 3. These descriptions were given not as a substitute for study of the Box-Jenkins technique,

but as a communication device to explain to the potential user of the Time Series Editor what happens in the various stages of the computational process, and to explain what the Editor requests mean. An example time series analysis covering all stages of the Box-Jenkins model building procedure was covered in Chapter 5. Appendices contain a User's Guide to the Time Series Editor, sample user sessions and program output, and program listings.

Although the Editor covers the entire model building process, as described by Box and Jenkins, from the plotting of the series to diagnostic testing and forecasting, much more could be added to improve the Editor's capability and utility. Listed below are several options that are recommended for addition to the Time Series Editor.

1. Extend the diagnostic ability to include a periodogram analysis or other tests related to the spectral analysis of time series.
2. Include an option that will determine all roots of the characteristic equation and give the general solution to the autocorrelation function and to the eventual forecast function.
3. Modify the FORECAST option to allow forecasts for seasonal nonstationary series'.
4. Modify the ESTIMATE option to provide parameter estimates for seasonal stationary series'.
5. Expand the univariate model building capability to linear transfer function model building.
6. Expand the Time Series Editor to include multivariate models such as multiple regression.

APPENDIX A

USER'S GUIDE TO TIME SERIES EDITOR

APPENDIX A: USER'S GUIDE TO TIME SERIES EDITOR

In order to use the Time Series Editor, the user must log onto CP, link to the disk storage area where the Time Series Editor resides, implement CMS, log into the general user and Time Series Editor disk areas, and enter the EXEC routine. It is also necessary to log out of the system at the completion of execution. The material which follows will enable the user to perform the above steps on the NPS CP/CMS system. Commands marked with an asterisk (*) are entered by the user (the asterisk itself is omitted). Those without an asterisk and those in all capital letters are system responses. Numbered sentences are comments which will not appear during an actual user session. The instructions and system responses assume an IBM 2741 Input/Output Terminal. Some modifications may be necessary if other terminals are used.

1. Turn the terminal on, depress the RETURN key, and wait for the system to respond:

```
CP-67 online   xd.65  qsyosu
```

2. Depress the ATTN key. The roll bar will advance and the keyboard will unlock. Then enter:

```
*login xxxxgnn
```

3. xxxx is the user's identification number, and nn is the terminal number (written on the right-hand-side of the terminal. For example, if the user's ID is 0655 and the terminal number is 07 the input would be:
login 0655g07

4. The system will respond with the statement:

```
ENTER PASSWORD:
```


5. The user then enters his password (most users at NPS have the password npg):

*npg
6. The system will then respond:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER
COST CENTER CODE:
7. The user then enters:

*aaaabbbb
8. aaaa is the assigned project number and bbbb is the user's section designator or faculty code.
9. The system will respond with the message of the day such as:

CP/CMS HRS.. 0930-2200(MON-THURS)..0930-1800(FRI) OUTPUT
RETAINED 4 DAYS
CMS VERSION 3.2
10. At this point the user is in CMS. He must then get in-
to CP. This is done by hitting the ATTN key. The
system will respond:

CP
11. The user must then link to the TIME SERIES EDITOR. This
is accomplished by entering:

*link 1969p 191 192
12. The system will respond with the instruction:

ENTER PASSWORD:
13. The user then enters:

*rfrr
14. The system will respond:

SET TO READ ONLY
15. The user must now implement CMS by entering:

*ipl cms
16. The system will respond:

CMS VERSION 3.2

17. Now the user must log into both his general user and the Time Series Editor area by entering:

*login 191
18. The system will respond with a message about the status of the file such as:

P(191):49 FILES; 225 REC IN USE, 71 LEFT (OF 296),
76% FULL (2 CYL)
R;
19. The user should then enter the command:

*login 192 t,p
R;
20. The system will respond:

T(192) R/O
R;
21. The user can then enter the Time Series Editor by issuing the command:

*timeser exec
22. The system will respond:

YOU HAVE ENTERED THE TIME SERIES EDITOR
PLEASE RESPOND TO EACH INQUIRY
etc.
23. The user is then on his own, guided by the Exec routine. See the notes that appear at the end of this Appendix for additional information. Eventually, the user will be asked:

DO YOU WANT TO TRY AGAIN?
24. If a yes response is given another sequence will begin. A no will take the user out of the Time Series Editor. The system response will be:

CONTROL RETURNED TO CMS
R;
25. The user then can log out by entering:

*cp logout
26. The system will respond:

CONNECT= 01.17.24 VIRTCPU= 001.03.37 TOTCPU= 001.30.14
LOGOUT AT 17.19.08 ON 3/21/77

27. The user should then turn off his terminal and tear off his output.

A sample of the procedure is shown below:

cp-67 online xd.65 qsyosu

login 0655g07

ENTER PASSWORD:

npg

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST
CENTER CODE:

0986rk54

CP/CMS HRS, MONDAY THRU THURSDAY, 0930-2200, FRIDAY, 0930-1800.

OUTPUT RETAINED 5 DAYS

READY AT 16.13.22 ON 03/22/77

CMS VERSION 3.2

offline read *

P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL
(2 CYL)

OFFLINE READ FILE FT02F001

R;

CP

link 1969p 191 192

ENTER PASSWORD:

rfrr

SET TO READ ONLY

ipl cms

CMS VERSION 3.2

login 191

P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL
(2 CYL)

R;

login 192 t,p

T (192) R/O

R;

timeser exec

YOU HAVE ENTERED THE TIME SERIES EDITOR

.
.
.
.

DO YOU WANT TO TRY AGAIN?

n

CONTROL RETURNED TO CMS

R;
cp log
CONNECT= 00.03.38 VIRTCPU= 000.00.34 TOTCPU= 000.01.30
LOGOUT AT 13.48.56 ON 3/11/77

NOTES:

- a. A typing error in CP/CMS can be corrected by typing the @ character as many times as is required to backup and then type the correct values. For example, the command exec timesre could be corrected by typing two @ signs followed by the correct letters er as follows:

exec timesre@@er

- b. An entire line can be deleted by typing the character ¢.
- c. The user should exercise care before depressing the return key. If an input is required and the return key is depressed before any character is entered, the user may get tossed out of the Editor. Before the return key is depressed, any errors can be corrected. After the return is hit there are only selected cases that can later be corrected.
- d. When asked to enter integer data, the user should always right justify the data within the allowed region.
- e. ** If at any time the user encounters a debug condition (probably caused by errors in entering data) and he cannot determine what needs to be done, he can get out of the debug condition by depressing the ATTN key twice. This puts the user back into CP from which he can link back to the Time Series Editor or logout.

APPENDIX B

SAMPLE USER SESSION AND PROGRAM OUTPUT

APPENDIX B: SAMPLE USER SESSION AND PROGRAM OUTPUT

cp-67 online xd.65 qsyosu

login 9655g07

ENTER PASSWORD:

npg

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:
0986rk54

CP/CMS HRS, MONDAY THRU THURSDAY, 0930-2200, FRIDAY, 0930-1800.

OUTPUT RETAINED 5 DAYS.

FILES:- 01 RDR, NO PRT, NO PUN

READY AT 16.13.22 ON 03/22/77

CMS VERSION 3.2

offline read *

P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL (2 CYL)

OFFLINE READ FILE FT02F001

R;

CP

link 1969p 191 192

ENTER PASSWORD:

rfrr

SET TO READ ONLY

ipl cms

CMS VERSION 3.2

login 191

P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL (2 CYL)

R;

login 192 t,p

T (192) R/O

R;

timeser exec

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.

ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.

ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES FOR NAMES STARTING WITH I THRU N.

TYPE INTEGER VALUES FOR COUNTS. TYPE FLOATING
VALUES WITH DECIMAL FOR ALL OTHER NAMES.

DO YOU WANT A LIST OF OPTIONS?

y

OPTION	DESCRIPTION
GENERATE	-----GENERATE ANY ARIMA TIME SERIES
AUTO	-----CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT	-----PLOT A TIME SERIES
DIFF	-----TRANSFORM AND DIFFERENCE A TIME SERIES
ESTIMATE	-----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
SIMULATE	-----SIMULATE TIME SERIES FROM A GIVEN MODEL
FORECAST	-----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS

WOULD YOU LIKE MORE INFO?

y

ENTER OPTION YOU WANT INFO ABOUT.

d

DIFF -----THIS PROGRAM TRANSFORMS A GIVEN TIME SERIES WITH A LOG OR AN EXPONENTIAL TRANSFORMATION (OR NO TRANSFORMATION IF DESIRED), AND THEN TAKES SEASONAL AND/OR SIMPLE DIFFERENCES OF ANY SPECIFIED ORDERS. IT THEN OUTPUTS THE TRANSFORMED AND DIFFERENCED TIME SERIES. THIS PROGRAM IS USED TO ATTEMPT TO MAKE A SEASONAL OR A NONSTATIONARY TIME SERIES OF THE FORM THAT CAN BE HANDLED VIA BOX-JENKINS TECHNIQUES. IT USES FTRDIF FROM THE IMSL LIBRARY.

DO YOU WANT TO TRY A SESSION?

y

ENTER THE LETTER FOR OPTION YOU WANT.

p

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ENTER TITLE FOR PLOT.

series c, original values.

TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE.

DO YOU WANT TO TRY AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

a

IS YOUR DATA IN FILE FT02F001?

y

*EXECUTION BEGINS...

AUTOCORRELATIONS

0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.570	0.523
0.468	0.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003

PARTIAL AUTOCORRELATIONS

0.978	-0.260	-0.157	-0.093	-0.058	-0.045	-0.012	-0.038	-0.022	-0.010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024

MEAN= 22.9739

VARIANCE = 4.22273

ENTER TITLE FOR PLOTS.

series C, original values.

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM 1140 UNDER YOUR USED ID NUMBER.

DO YOU WANT TO TRY AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

d

IS YOUR DATA IN FILE FT02F001?

Y

EXECUTION BEGINS...

IS YOUR TIME SERIES SEASONAL?

n

ENTER NUMBER OF NONSEASONAL DIFFERENCES.

1

DO YOU WANT A LOG TRANSFORMATION?

n

DO YOU WANT AN EXPONENTIAL TRANSFORMATION?

n

YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE FT03F001.

DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?

Y

THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:

0.400009	0.099991	0.0	0.0	0.0
-0.199997	-0.100006	-0.099991	-0.300003	-0.399994

DO YOU WANT TO PLOT AUTO ANDPAUTO OF TRANSFORMED DATA?

Y

*EXECUTION BEGINS...

AUTOCORRELATIONS

0.805	0.653	0.526	0.442	0.380	0.318	0.262	0.186	0.139	0.144
0.097	0.094	0.074	0.073	0.070	0.072	0.089	0.043	0.041	0.040

PARTIAL AUTOCORRELATIONS

0.805	0.010	-0.007	0.051	0.027	-0.019	-0.013	-0.080	0.020	0.117
-0.137	0.094	-0.027	0.034	0.006	0.012	0.043	-0.121	0.060	-0.005

MEAN=-.346667E-01

VARIANCE = 0.531982E-01

ENTER TITLE FOR PLOTS.

series C, 1st order differenced data.

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM 1140 UNDER YOUR USED ID NUMBER.

DO YOU WANT TO TRY AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

d

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

IS YOUR TIME SERIES SEASONAL?

n

ENTER NUMBER OF NONSEASONAL DIFFERENCES.

2

DO YOU WANT A LOG TRANSFORMATION?

n

DO YOU WANT AN EXPONENTIAL TRANSFORMATION?

n

YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE FT03F001.

DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?

y

THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:

-0.300018	-0.099991	0.0	0.0	-0.199997
0.099991	0.000015	-0.200012	-0.099991	0.199982

DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

y

EXECUTION BEGINS...

AUTOCORRELATIONS

-0.079	-0.065	-0.022	-0.063	0.013	-0.018	0.049	-0.052	-0.124	0.122
-0.122	0.072	-0.077	0.029	-0.011	-0.058	0.171	-0.101	-0.013	-0.020

PARTIAL AUTOCORRELATIONS

-0.079	-0.072	-0.135	-0.094	-0.022	-0.051	0.022	-0.060	-0.145	0.094
-0.143	0.023	-0.089	-0.005	-0.039	-0.074	0.130	-0.105	-0.014	-0.053

MEAN=-.267866E-02 VARIANCE = 0.198143E-01

ENTER TITLE FOR PLOTS.

series C, 2nd order differenced data.

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO TRY AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

e

*IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ENTER NUMBER OF AR PARAMETERS.

0

ENTER NUMBER OF MA PARAMETERS.

2

ENTER NUMBER OF DIFFERENCES.

2

* LENGTH OF TIME SERIES = 226

0 AR PARAMETERS 2 MA PARAMETERS 2 DIFFERENCES.

ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:

PHI(1) = 2.0000

PHI(2) = -1.0000

ESTIMATED MA PARAMETERS ARE:

THETA(1) = 0.1382

THETA(2) = 0.1300

MA CONSTANT= 0.0

WHITE NOISE VARIANCE= 0.189515E-01

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

Y

EXECUTION BEGINS...

AUTOCORRELATIONS

0.020	0.034	-0.134	-0.093	-0.012	-0.043	0.004	-0.063	-0.125	0.088
-0.142	0.069	-0.098	0.025	0.004	-0.055	0.157	-0.089	0.006	-0.006

PARTIAL AUTOCORRELATIONS

0.020	0.034	-0.135	-0.090	0.001	-0.055	-0.019	-0.071	-0.143	0.087
-0.166	0.017	-0.104	-0.013	-0.025	-0.090	0.123	-0.123	-0.021	-0.025

MEAN=-.124975E-02

VARIANCE = 0.189499E-01

ENTER TITLE FOR PLOTS.

series C, residuals of (0,2,2).

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO CHECK RESIDUALS?

Y

EXECUTION BEGINS...

ENTER IP, NO OF AR PARAMETERS (DIFFERENCED FORM).

0

ENTER IQ, NO OF MA PARAMETERS.

2

* CHI SQUARE LACK OF FIT VALUE = 28.74 DF = 18 SIGNIFICANCE = 0.0516

DO YOU WANT TO TRY AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

e

IS YOUR DATA IN FILE FT02F001?

Y

EXECUTION BEGINS...

ENTER NUMBER OF AR PARAMETERS.

1

ENTER NUMBER OF MA PARAMETERS.

0

ENTER NUMBER OF DIFFERENCES.

1

LENGTH OF TIME SERIES = 226

1 AR PARAMETERS 0 MA PARAMETERS 1 DIFFERENCES.

ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:

PHI(1) = 1.8131

PHI(2) = -0.8131

MA CONSTANT= 0.0

WHITE NOISE VARIANCE= 0.178396E-01

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

y

EXECUTION BEGINS...

AUTOCORRELATIONS

0.010	0.009	-0.053	-0.009	0.058	0.021	0.076	-0.020	-0.089	0.130
-0.095	0.083	-0.056	0.042	0.006	-0.041	0.169	-0.080	-0.001	-0.010

PARTIAL AUTOCORRELATIONS

0.010	0.009	-0.054	-0.008	0.060	0.018	0.074	-0.016	-0.088	0.140
-0.104	0.069	-0.048	0.041	0.003	-0.030	0.157	-0.087	0.013	-0.025

MEAN=-.897935E-02

VARIANCE = 0.177590E-01

ENTER TITLE FOR PLOTS.

series C, residuals of (1,1,0).

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO CHECK RESIDUALS?

y

EXECUTION BEGINS...

ENTER IP, NO OF AR PARAMETERS (DIFFERENCED FORM).

1

ENTER IQ, NO OF MA PARAMETERS.

0

* CHI SQUARE LACK OF FIT VALUE = 21.53 DF = 19 SIGNIFICANCE = 0.3082

DO YOU WANT TO TRY AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

f

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ARE YOUR PARAMETERS IN DIFFERENCED FORM?

y

ENTER NO. AR PARAMETERS (DIFF. FORM).

1

ENTER AR PARAMETER PHI(1).

0.8131

AR PARAMETERS ARE:

0.8131

ARE THESE OK?

Y

ENTER NUMBER OF MA PARAMETERS.

0

ENTER OVERALL MA CONSTANT

0

ENTER THE NUMBER OF DIFFERENCES.

1

ENTER INDEX FOR FORECAST ORIGIN VIA I3.

020

ENTER FORECAST LEAD TIME VIA I2.

13

ENTER SIGNIFICANCE LEVEL, ALPHA.

.2

MA CONSTANT = 0.0 NUMBER OF DIFFERENCES = 1

FORECAST LEAD TIME = 13 ALPHA = 0.200

ARE THESE OK?

Y

AR PARAMETERS IN UNDIFFERENCED FORM ARE:

1.8131

-0.8131

THE FORECASTS ARE:

23.1561	22.9577	22.7964	22.6653	22.5586
22.4719	22.4014	22.3440	22.2974	22.2594
22.2286	22.2035	22.1831		

80.0% CONFIDENCE LIMITS FOR FORECASTS ARE:

0.172546	0.357271	0.556689	0.761553	0.966487
1.16832	1.36521	1.55613	1.74057	1.91838
2.08959	2.25439	2.41304		

PSI WEIGHTS FOR FORECAST ERROR ARE:

1.81310	2.47423	3.01180	3.44889	3.80429
4.09326	4.32822	4.51927	4.67461	4.80092
4.90362	4.98712	5.05501		

WHITE NOISE VARIANCE = 0.18127E-01

DO YOU WANT TO PLOT FORECASTS?

Y

*DO YOU REALLY WANT TO PLOT FORECASTS?

Y

YOUR TIME SERIES AND FORECASTS ARE PLOTTED OFFLINE.

DO YOU WANT TO TRY AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

S

IS YOUR DATA IN FILE FT02F001?

Y

*EXECUTION BEGINS...

ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM).

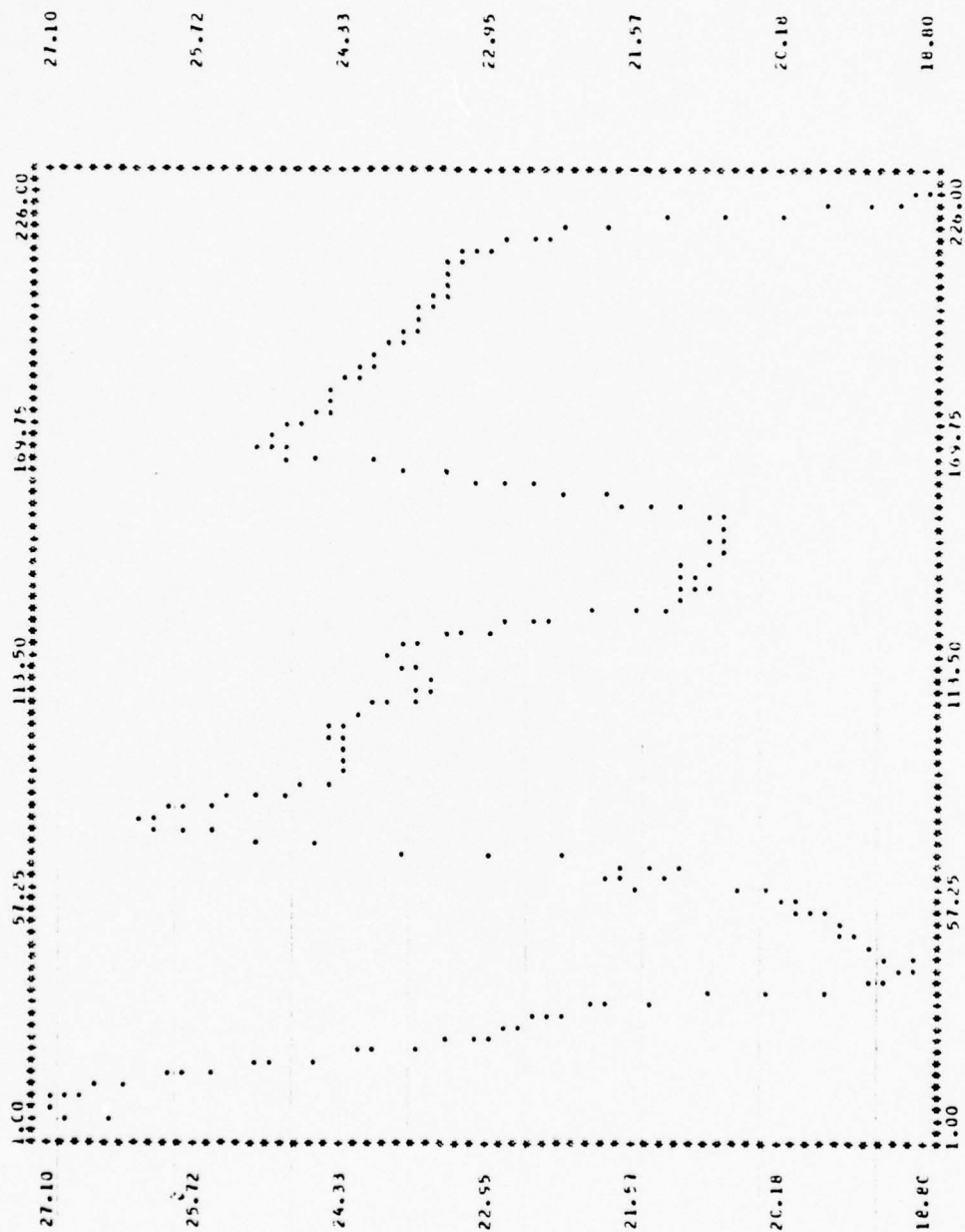
2

```

ENTER ESTIMATED AR PARAMETER PHI(1).
1.8131
ENTER ESTIMATED AR PARAMETER PHI(2).
-0.8131
AR PARAMETERS ARE          1.8131      -0.8131
ARE THESE OK?
Y
ENTER NUMBER OF MA PARAMETERS
0
ENTER OVERALL MA CONSTANT
0
ENTER ESTIMATED WHITE NOISE VAR
0.0178
DO YOU WANT TO INPUT STARTING VALUES?
n
START(1)=          19.000000
START(2)=          18.799988
STARTING VALUE(S) OK?
Y
ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).
0.7659376
ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA 13.
065
DO YOU WANT MORE THAN ONE SIMULATED SERIES?
Y
HOW MANY SERIES DO YOU WANT (LE.9)?
2
DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?
Y
SIMULATED VALUES ARE:
      18.640320      18.511963      18.631088      18.626831      18.787552
      18.963882      19.074707      19.205811      19.261063      19.633331
      19.821411      20.042175      20.166321      20.347610      20.369507
      20.216507      20.133179      20.174332      20.287857      20.241806
DO YOU WANT TO PLOT SIMULATED VALUES?
Y
EXECUTION BEGINS...
ENTER TITLE FOR PLOT.
simulations with model (1,1,0), series C.
TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE.

DO YOU WANT TO TRY AGAIN?
n
CONTROL RETURNED TO CMS
R;

```



X-SCALE: "X" = 0.201E 01 UNITS
Y-SCALE: "Y" = 0.138E 01 UNITS
SERIES C, ORIGINAL VALUES.

Figure 3. Plots of series C.

AUTOCORRELATIONS											
0.578	C.544	C.802	C.854	0.802	0.748	0.692	0.635	0.579	0.523		
0.468	C.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003		
PARTIAL AUTOCORRELATIONS											
0.578	-C.269	-C.157	-C.053	-0.058	-0.095	-0.012	-0.038	-0.022	-0.010		
-0.036	-0.041	-C.038	-C.024	-0.037	-0.027	-0.032	-0.070	-C.048	-0.024		
MEAN= 22.5735 VARIANCE = 4.22273											

Table I. Auto and partial autocorrelations of series C.

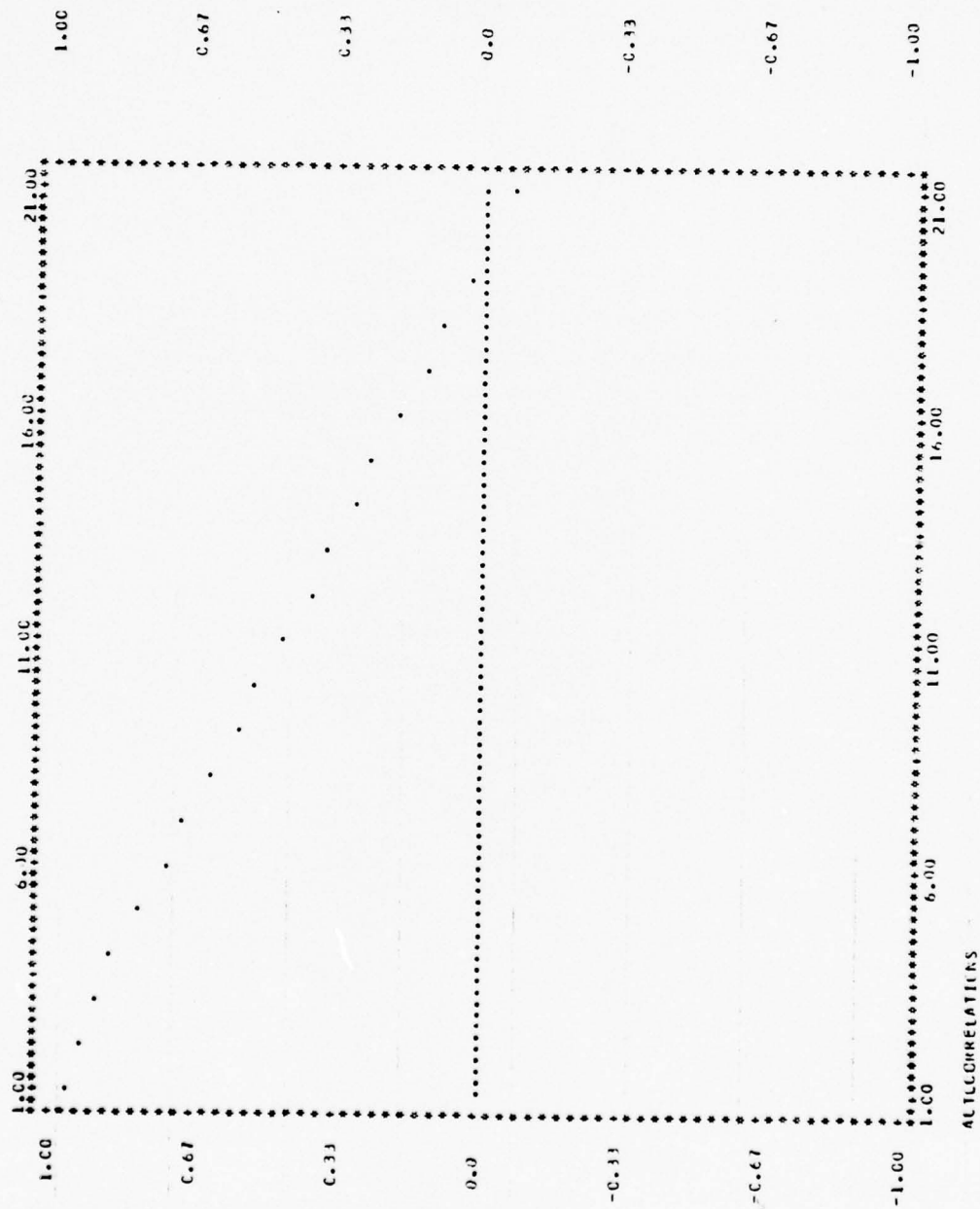


Figure 4. Plots of autocorrelations of series C.

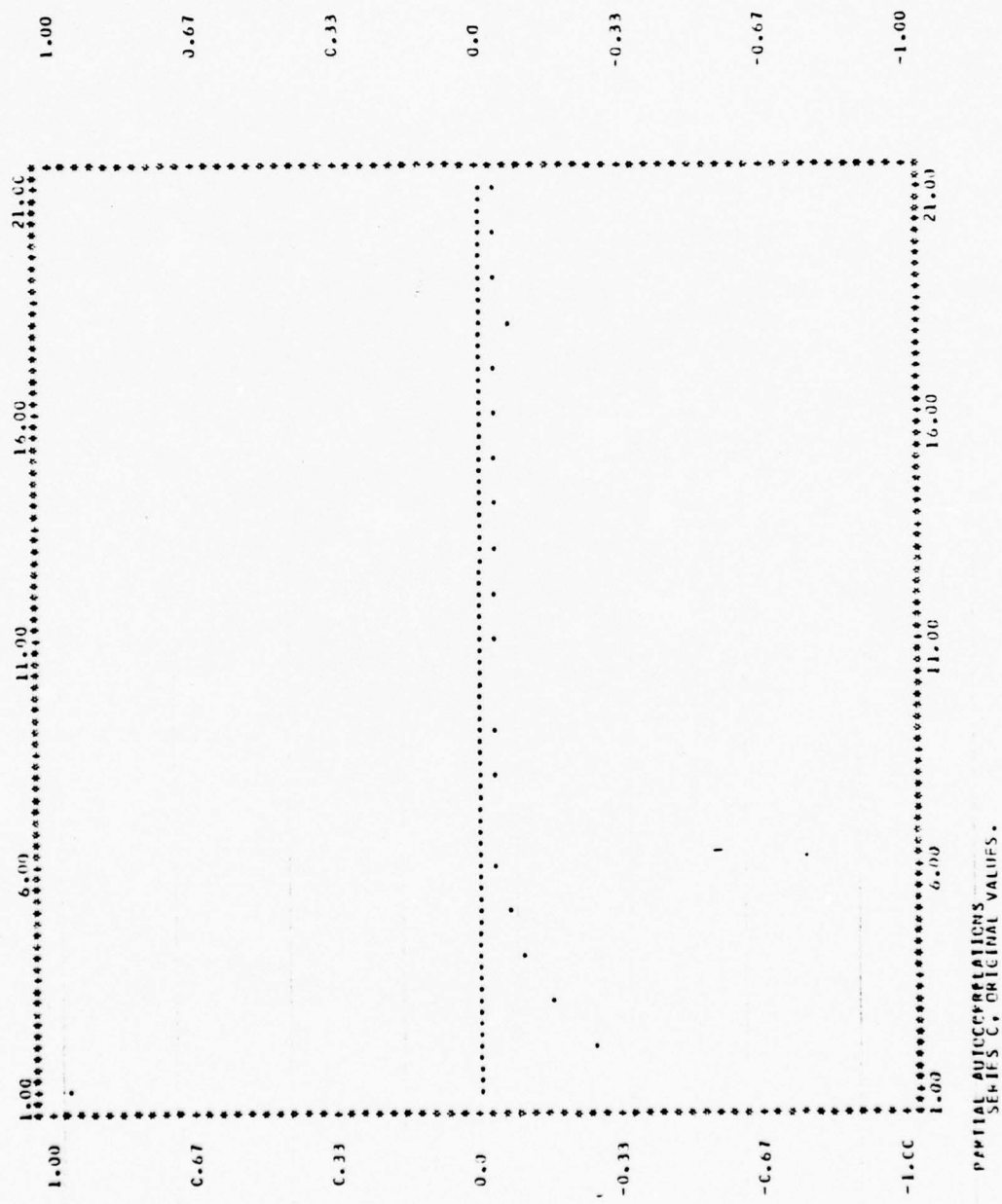


Figure 5. Plots of partial autocorrelations of series C.

AUTOCORRELATIONS											
0.805	C.453	C.526	C.442	0.480	0.318	C.262	0.106	C.139	0.149		
0.057	C.058	0.014	C.013	C.070	0.072	0.089	0.048	0.041	0.040		
PARTIAL AUTOCORRELATIONS											
0.805	C.010	-0.057	C.051	0.027	-0.019	-0.013	-0.080	0.020	0.117		
-0.137	0.054	-0.027	0.034	0.006	0.012	0.043	-0.121	0.050	-0.005		
MEAN = -0.246667E-01 VARIANCE = 0.511982E-01											

Table III. Auto and partial autocorrelations of 1st differenced series C.

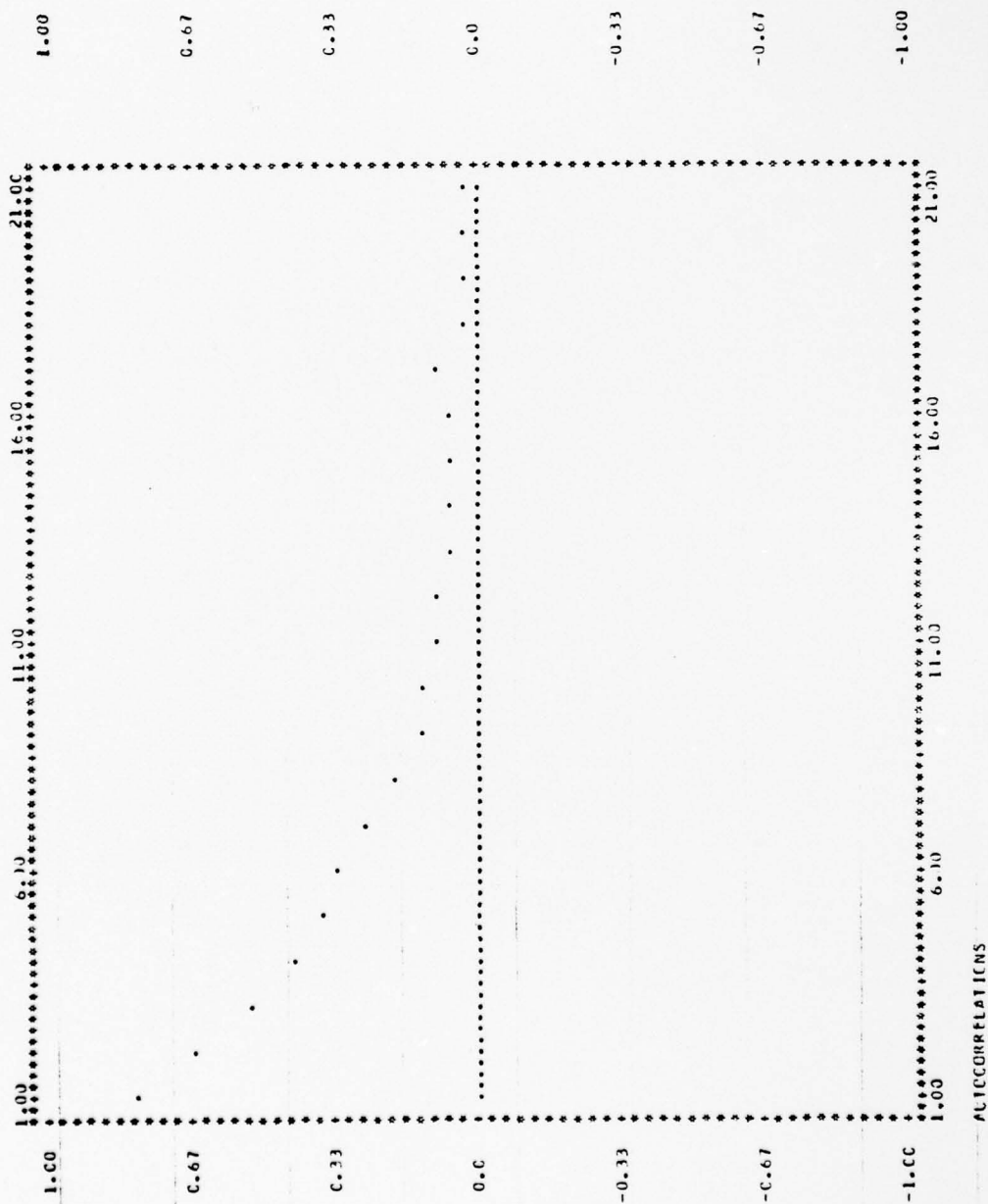


Figure 6. Plots of autocorrelations of 1st differenced series C.

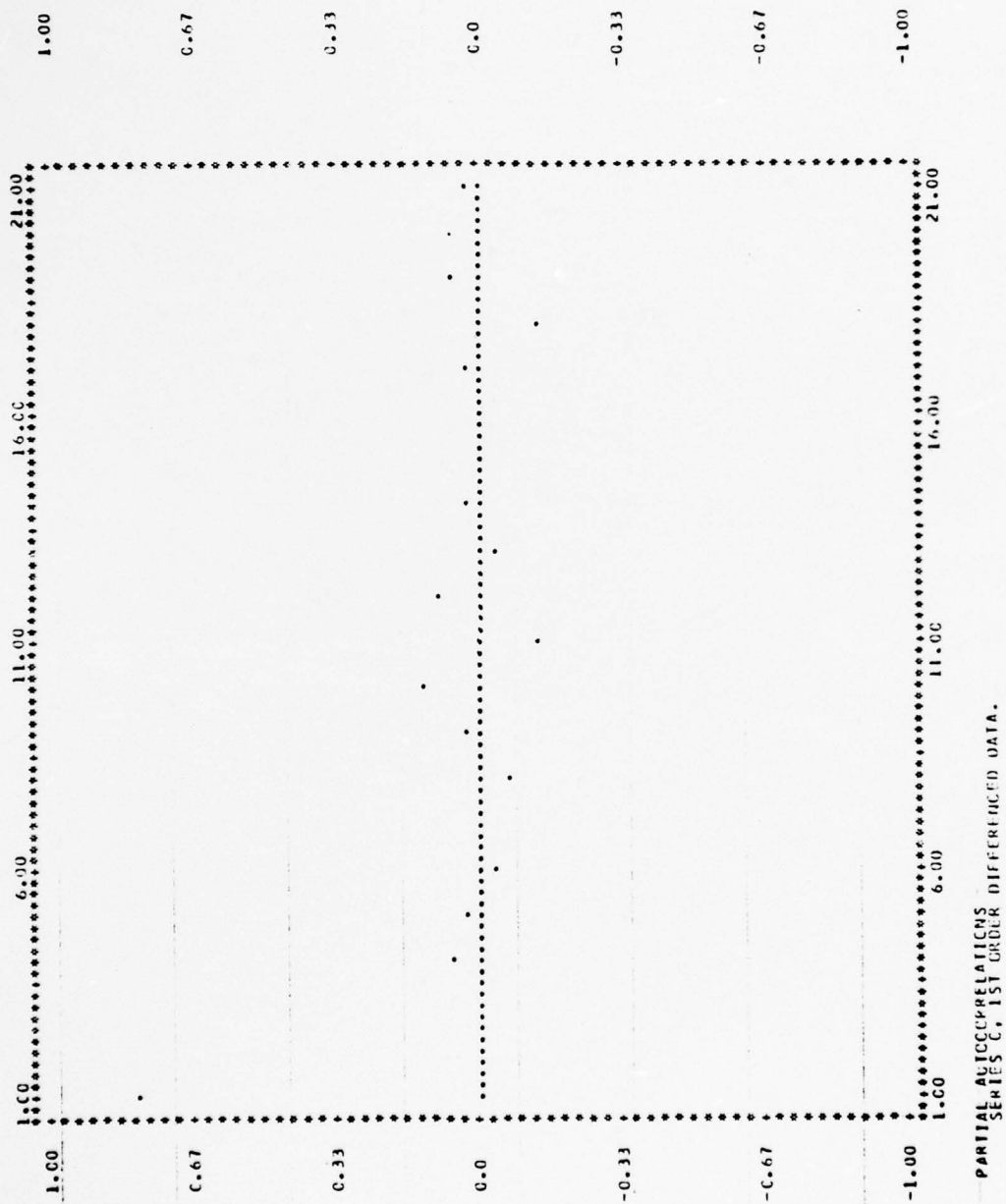


Figure 7. Plots of partial autocorrelations of 1st differenced series C.

[illegible]

Values of 2nd differenced series C.

AUTOCORRELATIONS

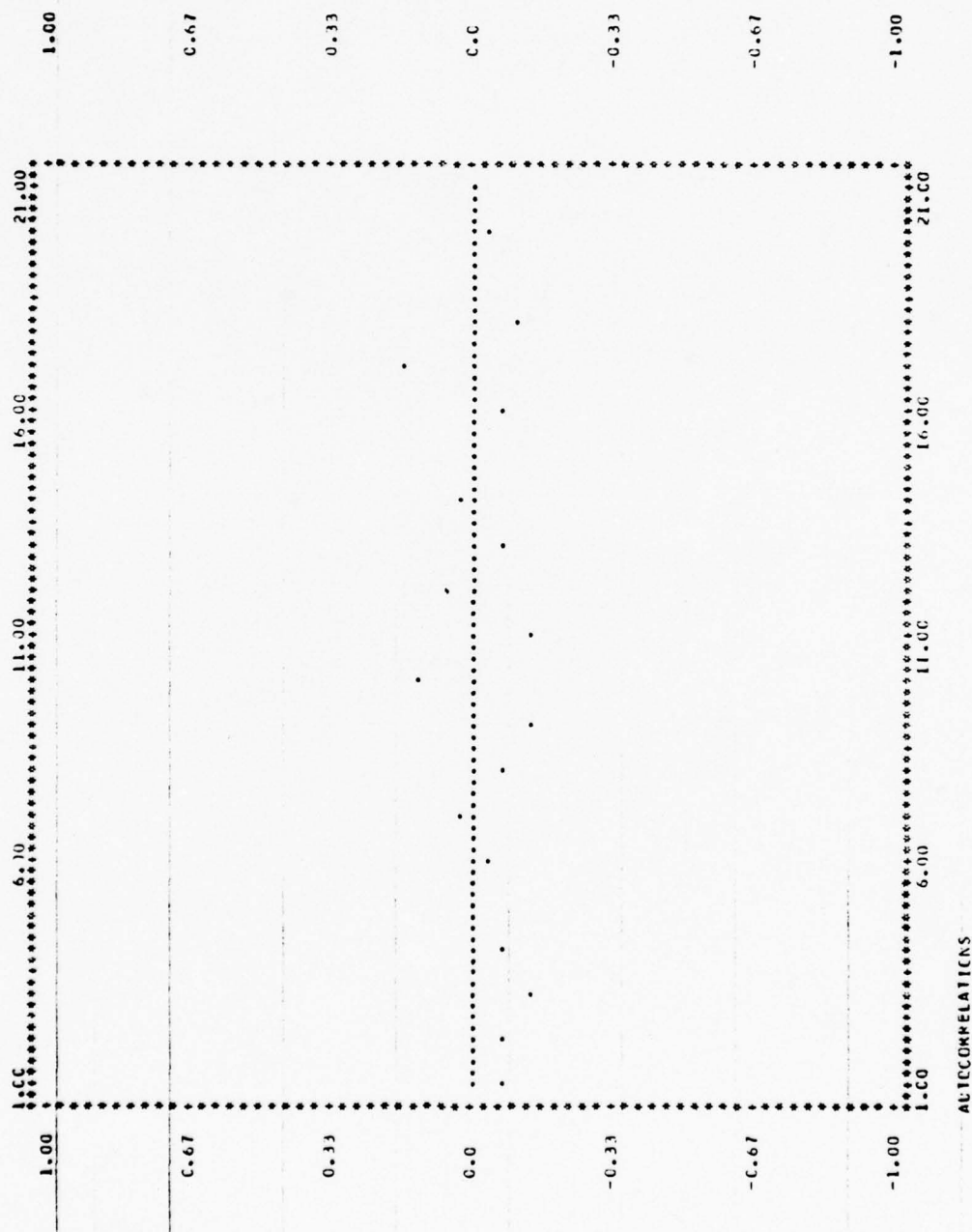
-0.079 -0.065 -0.122 -0.063 0.013 -0.018 0.049 -0.052 -0.124 0.122
-0.122 0.092 -0.077 0.029 -0.011 -0.058 0.171 -0.101 -0.013 -0.020

PARTIAL AUTOCORRELATIONS

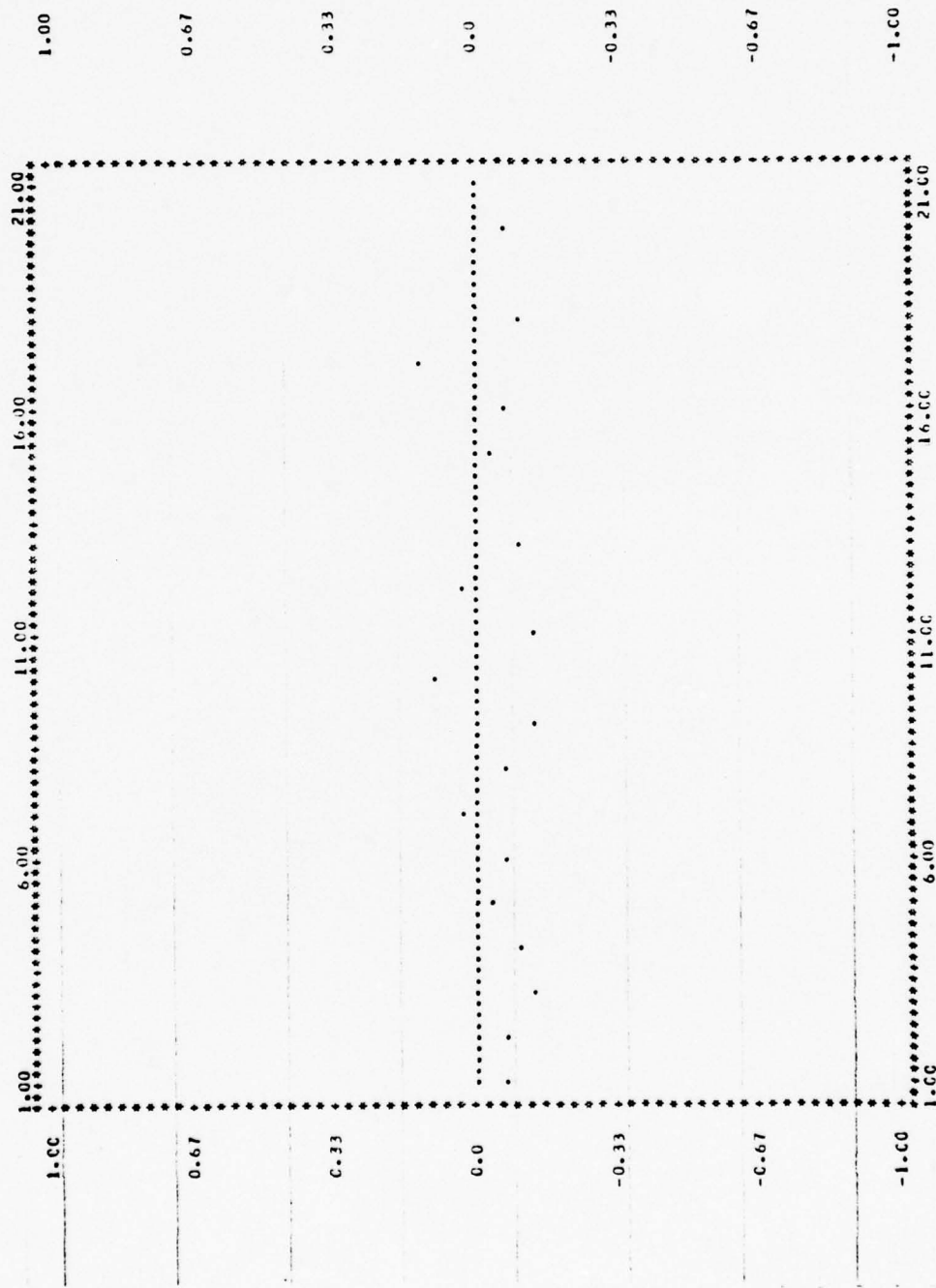
-0.079 -0.072 -0.135 -0.054 -0.022 -0.051 0.022 -0.060 -0.145 0.054
-0.143 0.023 -0.089 -0.065 -0.039 -0.074 0.130 -0.105 -0.014 -0.053

MEAN = -0.261866E-02 VARIANCE = 0.198143E-01

Auto and partial autocorrelations of 2nd differenced series C.



Plots of autocorrelations of 2nd differenced series C.



PARTIAL AUTOCORRELATIONS
SERIES C, 2ND ORDER DIFFERENCED DATA.

FILE: FILE FTC3F001 PL

PAGE CCI

NAVAL POSTGRADUATE SCHOOL

[illegible]

Residuals of (1.1.0) model of series C.

AUTOCORRELATIONS

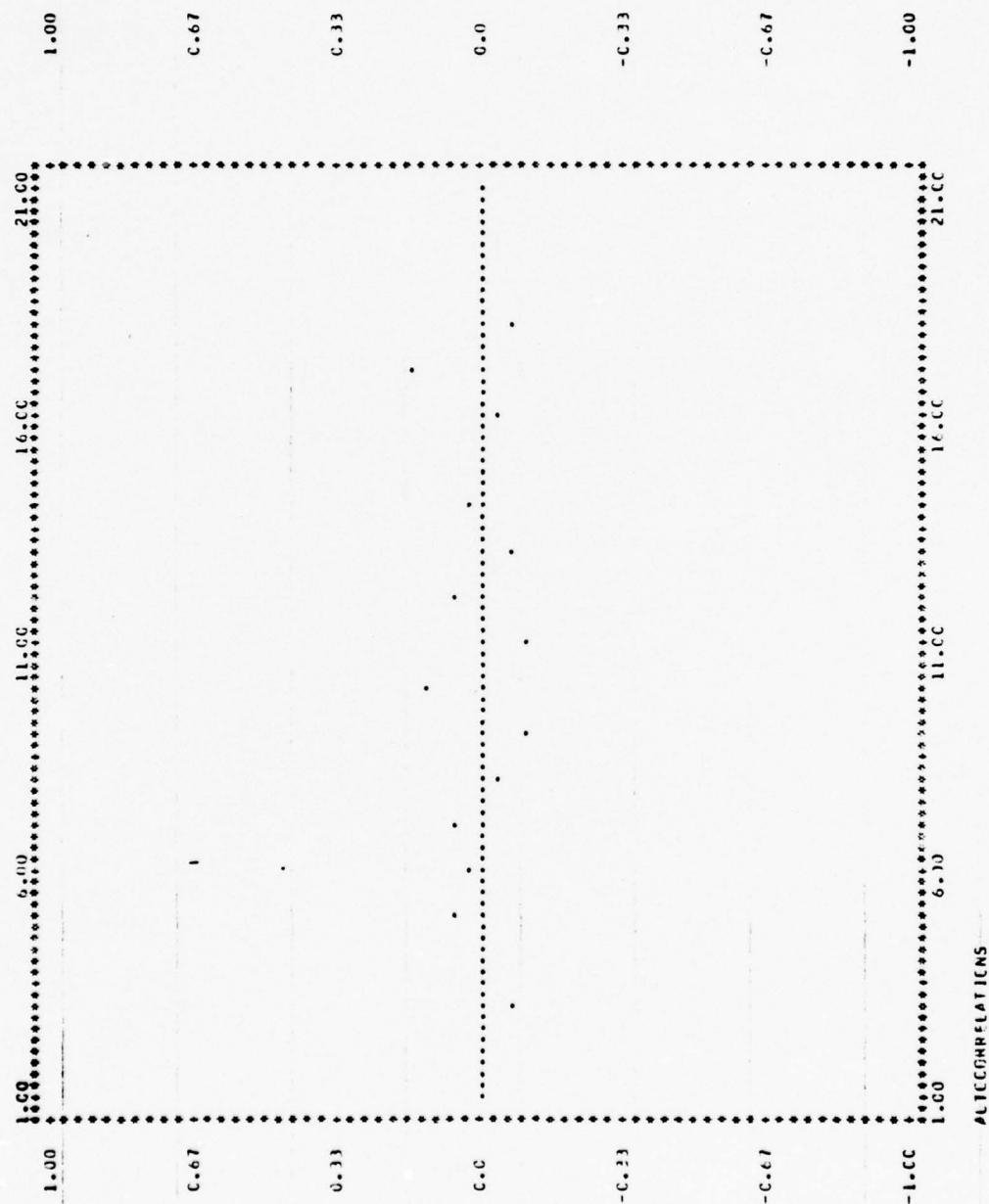
0.010	0.005	-0.053	-0.005	0.058	0.071	0.016	-0.029	-0.089	0.130
-0.055	0.083	-0.056	0.042	0.006	-0.041	0.169	-0.080	-0.001	-0.010

PARTIAL AUTOCORRELATIONS

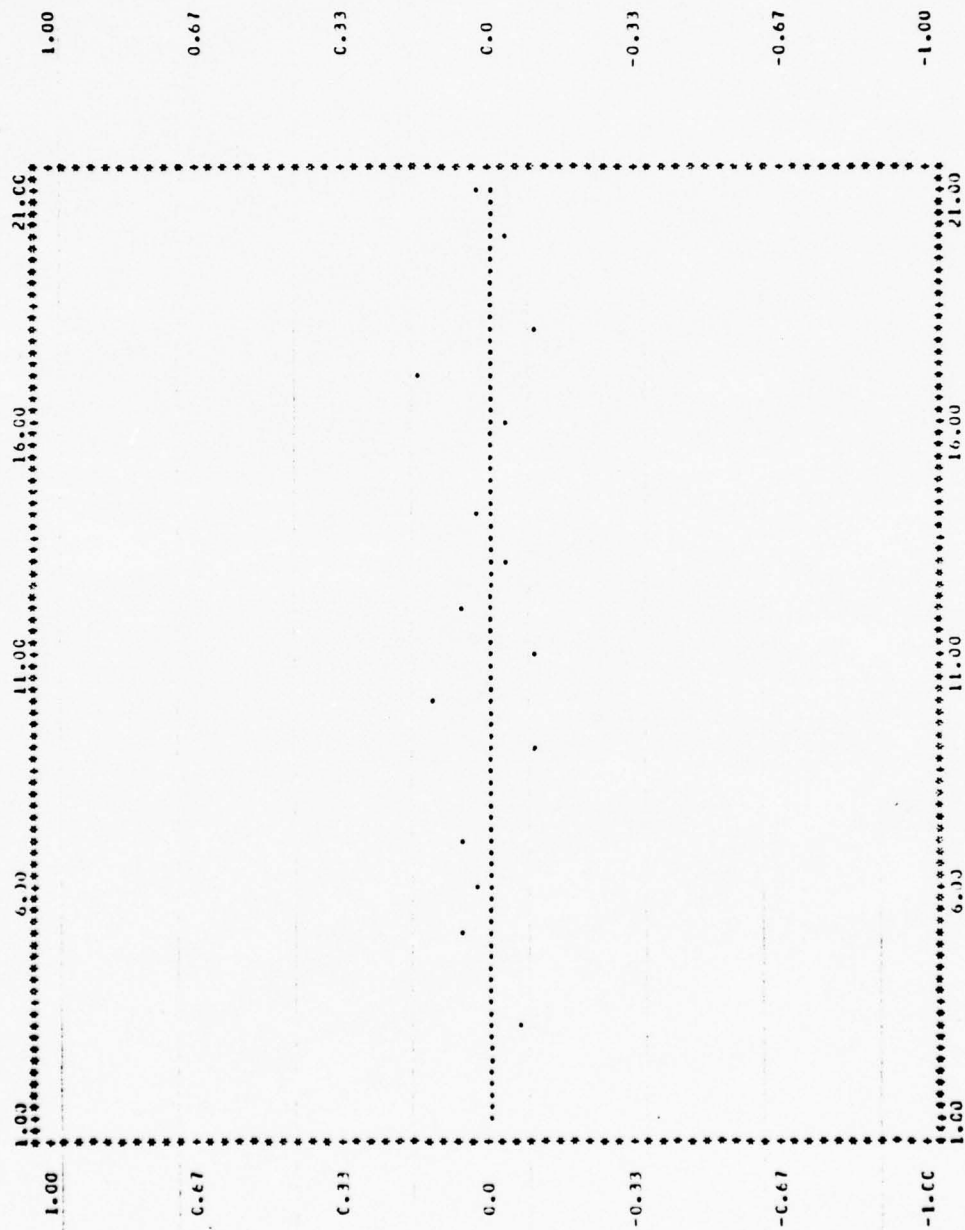
0.010	0.009	-0.054	-0.008	0.060	0.018	0.074	-0.016	-0.008	0.140
-0.004	0.069	-0.048	0.041	0.003	-0.010	0.157	-0.087	0.013	-0.025

MEAN = -.897935E-02 VARIANCE = 0.175900E-01

Auto and partial autocorrelations of residuals of (1,1,0) model.



Plots of autocorrelations of residuals, model (1,1,0) of series C.



PARTIAL AUTOCORRELATIONS
SERIES C, RESIDUALS OF (1,1,0).

AUTOCORRELATIONS

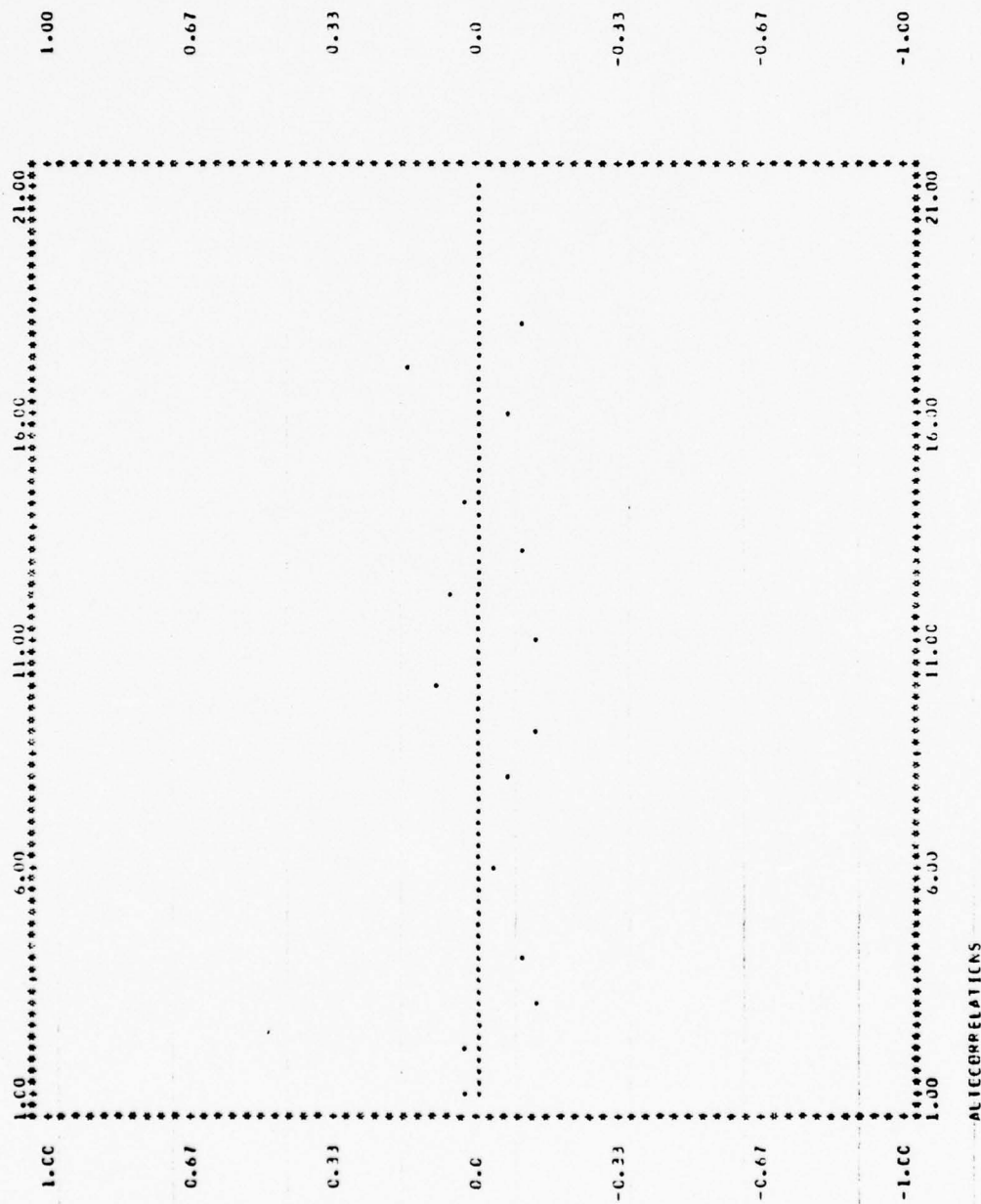
C-020 C-034 -0.134 -0.053 -0.012 -0.043 0.004 -0.063 -0.125 0.088
 -0.142 C-069 -0.098 C-025 0.004 -0.055 0.157 -0.089 C-006 -0.002

PARTIAL AUTOCORRELATIONS

C-020 0.034 -0.135 -0.050 0.001 -0.055 -0.019 -0.071 -0.143 0.087
 -0.166 0.017 -0.104 -0.012 -0.025 -0.090 0.123 -0.123 -0.021 -0.025

MEAN = -0.124515E-02 VARIANCE = 0.107999E-01

Auto and partial autocorrelations of residuals, model (0.2.2) of series C.



Plots of autocorrelations of residuals, model (0,2,2) of series C.



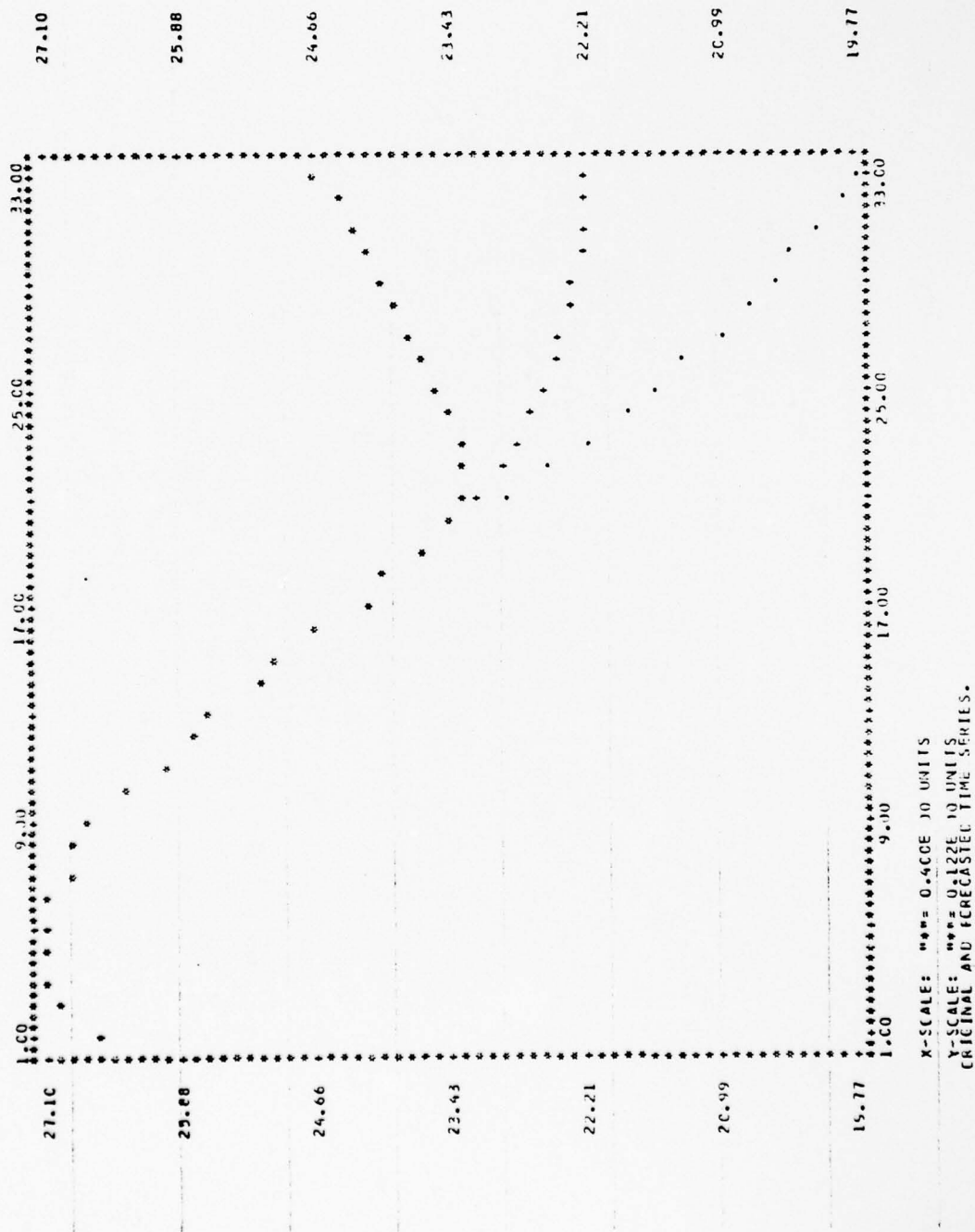


Figure 8. Plots of the forecasted values adjoined to the original series with 80% confidence limits about the forecasts.

[illegible]

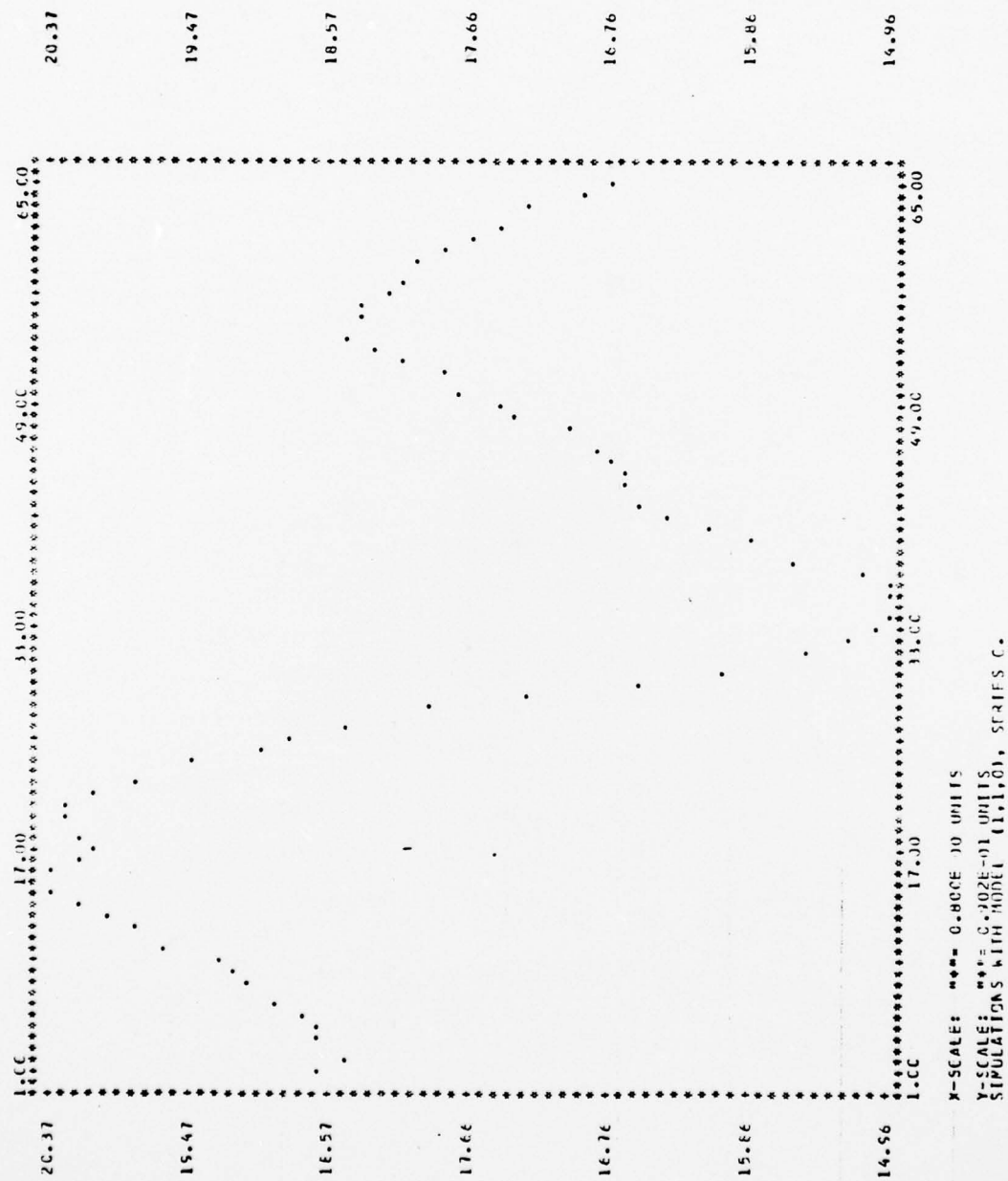


Figure 9. Plots of simulated series with model (1,1,0) of series C.

APPENDIX C

PROGRAM LISTINGS

85

86

PAGE 003

NAVAL POSTGRADUATE SCHOOL

FILE: TIMESER EXEC P1
GPRINT ENTER SERIES OFFLINE AND RETURN.
GCTC -END
-PCW PRINTF ENTER PARA
GCTC -LEE
-END GPRINT CONTROL RETURNED TO CMS
CEXIT

NAVAL POSTGRADUATE SCHOOL

EXEC PI

FILE: 15

[illegible]

```
FILE: TS EXEC PI
CELINE PRINT FILE FIOF00L PI
ALTER FILE CFCFCI PI FILE FIOF00L PI
WATER PCT (CLEAR XCH ACAP) FIOF00L PI
LOAD PCT (CLEAR XCH ACAP) FIOF00L PI
ALTER FILE PRINTCFCI FIOF00L PI
CELINE PRINTCFCI FIOF00L PI
WATER PCT FIOF00L PI FILE FIOF00L PI
GEAC I
EGOTIC -LES
TALON LAD: REGRESS (CLEAR XCQ NQMAPI)
STAYEY PRINT AGAIN?
GEAR ARS
GEAR M
GEAR H
EQ Y &GOTIC -ASK
PRINT CCATROL RETURNEC TC CMS.
```

Pt C0020
Pt C0019
Pt C0018
Pt C0017
Pt C0016
Pt C0015
Pt C0014
Pt C0013
Pt C0012
Pt C0011
Pt C0010
Pt C0009
Pt C0008
Pt C0007
Pt C0006
Pt C0005
Pt C0004
Pt C0003
Pt C0002
Pt C0001

91

FILE: DIFF FORTAAN P1 NAVAL POSTGRADUATE SCHOOL

```

DIMENSION Z(400)
DATA Y/100, 12
FORMAT(10,1) 1Z
200 READ(1,20) ((Z(I),I=1,12)
201 FORMAT(12E12.6)
IS=1
ID2=0
ID1=0
WRITE(5,605)
605 FORMAT(2X,'IS YOUR TIME SERIES SEASONAL?')
READ(5,502) ANS
IF(ANS.NE.1) GO TO 1000
20 FORMAT(10,1) 1Z
601 READ(1,20) ((Z(I),I=1,12)
602 FORMAT(12E12.6)
503 FORMAT(11)
10 WRITE(6,604)
604 FORMAT(2X,'ENTER LENGTH OF SEASONAL PERIOD VIA 12.')
504 READ(5,504) IS
505 FORMAT(12)
WRITE(6,605) IS
605 FORMAT(2X,'YOUR INPUT SEASONAL PERIOD= ',12,'. IS IT OK?')
READ(5,505) ANS
IF(ANS.NE.1) GO TO 10
1000 FORMAT(10,1) 1Z
600 READ(1,20) ((Z(I),I=1,12)
601 FORMAT(12E12.6)
WRITE(6,602)
602 FORMAT(2X,'DO YOU WANT A LOG TRANSFORMATION?')
READ(5,502) ANS
502 FORMAT(11)
IP=0
IF(ANS.EQ.1) GO TO 50
WRITE(6,603)
603 FORMAT(2X,'DO YOU WANT AN EXPONENTIAL TRANSFORMATION?')
READ(5,503) ANS
IF(ANS.NE.1) GO TO 50
WRITE(6,604)
604 FORMAT(2X,'ENTER POWER OF EXPONENTIAL TRANSFORMATION VIA 11.')
READ(5,504) IP
50 CALL FROTH(101,102,10,15,12,12,SHIFT,LM,IP)
P=LN
WRITE(6,500)
500 FORMAT(2X,'YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE',
* ' F103601.72X,'DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?')
READ(5,505) ANS
IF(ANS.NE.1) GO TO 525
WRITE(6,506)
606 FORMAT(2X,'THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:')
J=1
J2=1
IF(M.GT.10) J2=11
WRITE(6,607) ((Z(I),I=1,J2)
607 FORMAT(5F15.6)
525 WRITE(6,608)
608 FORMAT(11)
WRITE(6,609) ((Z(I),I=1,M)
609 FORMAT(5E15.6)
610 WRITE(6,610)
611 FORMAT(10,1) 1Z
612 READ(1,20) ((Z(I),I=1,12)
613 FORMAT(12E12.6)
614 WRITE(6,614)
615 FORMAT(2X,'ENTER ERROR PARAM= ',13,' SEE EXPLANATION IN SUPROUTINE FROTH')
616 READ(5,616)
617 FORMAT(12)
70 STOP
END

```


[illegible]

```

C37223777 IC:22:51
FILE: FORECAST FORTRAN F1          NAVAL POSTGRADUATE SCHOOL
DIMENSION X(400),ARPS(10),PMAS(20),LV(5),CARPS(20),FCST(3,20)
DATA Y(1),Y(2),Y(3),Y(4),Y(5),Y(6),Y(7),Y(8),Y(9),Y(10),Y(11),Y(12),Y(13),Y(14),Y(15),Y(16),Y(17),Y(18),Y(19),Y(20),Y(21),Y(22),Y(23),Y(24),Y(25),Y(26),Y(27),Y(28),Y(29),Y(30),Y(31),Y(32),Y(33),Y(34),Y(35),Y(36),Y(37),Y(38),Y(39),Y(40),Y(41),Y(42),Y(43),Y(44),Y(45),Y(46),Y(47),Y(48),Y(49),Y(50),Y(51),Y(52),Y(53),Y(54),Y(55),Y(56),Y(57),Y(58),Y(59),Y(60),Y(61),Y(62),Y(63),Y(64),Y(65),Y(66),Y(67),Y(68),Y(69),Y(70),Y(71),Y(72),Y(73),Y(74),Y(75),Y(76),Y(77),Y(78),Y(79),Y(80),Y(81),Y(82),Y(83),Y(84),Y(85),Y(86),Y(87),Y(88),Y(89),Y(90),Y(91),Y(92),Y(93),Y(94),Y(95),Y(96),Y(97),Y(98),Y(99),Y(100),Y(101),Y(102),Y(103),Y(104),Y(105),Y(106),Y(107),Y(108),Y(109),Y(110),Y(111),Y(112),Y(113),Y(114),Y(115),Y(116),Y(117),Y(118),Y(119),Y(120),Y(121),Y(122),Y(123),Y(124),Y(125),Y(126),Y(127),Y(128),Y(129),Y(130),Y(131),Y(132),Y(133),Y(134),Y(135),Y(136),Y(137),Y(138),Y(139),Y(140),Y(141),Y(142),Y(143),Y(144),Y(145),Y(146),Y(147),Y(148),Y(149),Y(150),Y(151),Y(152),Y(153),Y(154),Y(155),Y(156),Y(157),Y(158),Y(159),Y(160),Y(161),Y(162),Y(163),Y(164),Y(165),Y(166),Y(167),Y(168),Y(169),Y(170),Y(171),Y(172),Y(173),Y(174),Y(175),Y(176),Y(177),Y(178),Y(179),Y(180),Y(181),Y(182),Y(183),Y(184),Y(185),Y(186),Y(187),Y(188),Y(189),Y(190),Y(191),Y(192),Y(193),Y(194),Y(195),Y(196),Y(197),Y(198),Y(199),Y(200),Y(201),Y(202),Y(203),Y(204),Y(205),Y(206),Y(207),Y(208),Y(209),Y(210),Y(211),Y(212),Y(213),Y(214),Y(215),Y(216),Y(217),Y(218),Y(219),Y(220),Y(221),Y(222),Y(223),Y(224),Y(225),Y(226),Y(227),Y(228),Y(229),Y(230),Y(231),Y(232),Y(233),Y(234),Y(235),Y(236),Y(237),Y(238),Y(239),Y(240),Y(241),Y(242),Y(243),Y(244),Y(245),Y(246),Y(247),Y(248),Y(249),Y(250),Y(251),Y(252),Y(253),Y(254),Y(255),Y(256),Y(257),Y(258),Y(259),Y(260),Y(261),Y(262),Y(263),Y(264),Y(265),Y(266),Y(267),Y(268),Y(269),Y(270),Y(271),Y(272),Y(273),Y(274),Y(275),Y(276),Y(277),Y(278),Y(279),Y(280),Y(281),Y(282),Y(283),Y(284),Y(285),Y(286),Y(287),Y(288),Y(289),Y(290),Y(291),Y(292),Y(293),Y(294),Y(295),Y(296),Y(297),Y(298),Y(299),Y(300),Y(301),Y(302),Y(303),Y(304),Y(305),Y(306),Y(307),Y(308),Y(309),Y(310),Y(311),Y(312),Y(313),Y(314),Y(315),Y(316),Y(317),Y(318),Y(319),Y(320),Y(321),Y(322),Y(323),Y(324),Y(325),Y(326),Y(327),Y(328),Y(329),Y(330),Y(331),Y(332),Y(333),Y(334),Y(335),Y(336),Y(337),Y(338),Y(339),Y(340),Y(341),Y(342),Y(343),Y(344),Y(345),Y(346),Y(347),Y(348),Y(349),Y(350),Y(351),Y(352),Y(353),Y(354),Y(355),Y(356),Y(357),Y(358),Y(359),Y(360),Y(361),Y(362),Y(363),Y(364),Y(365),Y(366),Y(367),Y(368),Y(369),Y(370),Y(371),Y(372),Y(373),Y(374),Y(375),Y(376),Y(377),Y(378),Y(379),Y(380),Y(381),Y(382),Y(383),Y(384),Y(385),Y(386),Y(387),Y(388),Y(389),Y(390),Y(391),Y(392),Y(393),Y(394),Y(395),Y(396),Y(397),Y(398),Y(399),Y(400),Y(401),Y(402),Y(403),Y(404),Y(405),Y(406),Y(407),Y(408),Y(409),Y(410),Y(411),Y(412),Y(413),Y(414),Y(415),Y(416),Y(417),Y(418),Y(419),Y(420),Y(421),Y(422),Y(423),Y(424),Y(425),Y(426),Y(427),Y(428),Y(429),Y(430),Y(431),Y(432),Y(433),Y(434),Y(435),Y(436),Y(437),Y(438),Y(439),Y(440),Y(441),Y(442),Y(443),Y(444),Y(445),Y(446),Y(447),Y(448),Y(449),Y(450),Y(451),Y(452),Y(453),Y(454),Y(455),Y(456),Y(457),Y(458),Y(459),Y(460),Y(461),Y(462),Y(463),Y(464),Y(465),Y(466),Y(467),Y(468),Y(469),Y(470),Y(471),Y(472),Y(473),Y(474),Y(475),Y(476),Y(477),Y(478),Y(479),Y(480),Y(481),Y(482),Y(483),Y(484),Y(485),Y(486),Y(487),Y(488),Y(489),Y(490),Y(491),Y(492),Y(493),Y(494),Y(495),Y(496),Y(497),Y(498),Y(499),Y(500),Y(501),Y(502),Y(503),Y(504),Y(505),Y(506),Y(507),Y(508),Y(509),Y(510),Y(511),Y(512),Y(513),Y(514),Y(515),Y(516),Y(517),Y(518),Y(519),Y(520),Y(521),Y(522),Y(523),Y(524),Y(525),Y(526),Y(527),Y(528),Y(529),Y(530),Y(531),Y(532),Y(533),Y(534),Y(535),Y(536),Y(537),Y(538),Y(539),Y(540),Y(541),Y(542),Y(543),Y(544),Y(545),Y(546),Y(547),Y(548),Y(549),Y(550),Y(551),Y(552),Y(553),Y(554),Y(555),Y(556),Y(557),Y(558),Y(559),Y(560),Y(561),Y(562),Y(563),Y(564),Y(565),Y(566),Y(567),Y(568),Y(569),Y(570),Y(571),Y(572),Y(573),Y(574),Y(575),Y(576),Y(577),Y(578),Y(579),Y(580),Y(581),Y(582),Y(583),Y(584),Y(585),Y(586),Y(587),Y(588),Y(589),Y(590),Y(591),Y(592),Y(593),Y(594),Y(595),Y(596),Y(597),Y(598),Y(599),Y(600),Y(601),Y(602),Y(603),Y(604),Y(605),Y(606),Y(607),Y(608),Y(609),Y(610),Y(611),Y(612),Y(613),Y(614),Y(615),Y(616),Y(617),Y(618),Y(619),Y(620),Y(621),Y(622),Y(623),Y(624),Y(625),Y(626),Y(627),Y(628),Y(629),Y(630),Y(631),Y(632),Y(633),Y(634),Y(635),Y(636),Y(637),Y(638),Y(639),Y(640),Y(641),Y(642),Y(643),Y(644),Y(645),Y(646),Y(647),Y(648),Y(649),Y(650),Y(651),Y(652),Y(653),Y(654),Y(655),Y(656),Y(657),Y(658),Y(659),Y(660),Y(661),Y(662),Y(663),Y(664),Y(665),Y(666),Y(667),Y(668),Y(669),Y(670),Y(671),Y(672),Y(673),Y(674),Y(675),Y(676),Y(677),Y(678),Y(679),Y(680),Y(681),Y(682),Y(683),Y(684),Y(685),Y(686),Y(687),Y(68
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NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF
AN APPLICATION OF CP/CMS TO THE TIME SERIES ANALYSIS.(U)
MAR 77 Y W LEE

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FILE: CENRTE FCRTRAN PI

PAGE CCI

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DIMENSION P(10),THETA(6),START(6),W(400),WA(410)
DATA P(1),P(2),P(3),P(4),P(5),P(6),P(7),P(8),P(9),P(10),
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P(681),P(682),P(683),P(684
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C2422/11 CS-40.25

FILE: OPTICS PARA P5

NAVAL POSTGRADUATE SCHOOL

PAGE 001

OPTION DESCRIPTION
GENERATE ---- GENERATE ANY ARMA TIME SERIES
AUTO ---- CALCULATE AUTOCORRELATIONS, PLOTS, MEAN AND VARIANCE
PLOT ---- PLOT A TIME SERIES
DIFF ---- TRANSFORM AND DIFFERENCE A TIME SERIES
ESTIMATE ---- CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
SIMULATE ---- SIMULATE TIME SERIES FROM A GIVEN MODEL
FORECAST ---- FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS

TIME2050
TIME2050
TIME2050
TIME2050
TIME2050

(2/10/77 15-20-1)

FILE: P

PARA

PS

NAVAL POSTGRADUATE SCHOOL
FOLLOWS A GIVEN TIME SERIES WHICH RESIDES IN
FILE 1102FOL. IT USES THE PLUMP PROGRAM IN THE 1104 SSPLIB.

PAGE 001

C3/16/77 15-15-50

FILE: A PARA P5

NAVAL POSTGRADUATE SCHOOL
AUTO-----THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
-----IT MUST RESIDE IN FILE FT02F001. THE PROGRAM USES
STANDARD FORTRAN 77. THE AUTOCORRELATIONS AND PLOTS CAN BE
PLOTTED OFFLINE.

PAGE CCI

S

C3/16/77 15.15.55

FILE: D PARA PS

NAVAL POSTGRADUATE SCHOOL

PAGE CCI

DIFFERENTIAL TRANSFORMS A GIVEN TIME SERIES WITH A LOG
TRANSFORMATION (OR NO TRANSFORMATION IF DESIRED) AND
THEN TESTS FOR SEASONAL AND/OR SIMPLE DIFFERENCES OF ANY SPECIFIED ORDER.
IT THEN TESTS FOR NONSTATIONARITY AND DIFFERENCES OF ANY SPECIFIED ORDER.
PROGRAM IS USED TO ATTEMPT TO MAKE A SEASONAL OR A NONSTATIONARY TIME
SERIES OF THE FORM THAT CAN BE HANDLED VIA BOX-JENKINS TECHNIQUES. IT
USES FIRST FOR THE INSL LIBRARY.

03/22/77 (S.4).3C

FILE: E

PARA

P5

NAVAL POSTGRADUATE SCHOOL

ESTIMATE ---- THIS PROGRAM CALCULATES MAXIMUM LIKELIHOOD ESTIMATES OF THE
AUTOREGRESSIVE AND THE MOVING AVERAGE PARAMETERS OF AN ARMA MODEL.
IT ALSO DETERMINES THE RESIDUALS WHICH CAN BE USED TO CHECK OUT THE
MODEL. IT USES THE PROGRAM FMAXL FROM THE IMSL LIBRARY.

PAGE 001

C3/22/77 05.47.45

FILE: F

PARA

PI

NAVAL POSTGRADUATE SCHOOL

FORECAST ----- THIS PROGRAM TAKES A GIVEN ARIMA MODEL WITH PARAMETERS THAT HAVE ALREADY BEEN ESTIMATED AND CALCULATES FORECASTS OF FUTURE VALUES. IT ALSO DETERMINES CONFIDENCE LIMITS FOR THE VALUES THAT HAVE BEEN FORECASTED.

PAGE 001

03/10/77 15.20.12

FILE: S

PARA

P1

NAVAL POSTGRADUATE SCHOOL

PAGE 001

SIMULATE ---- THIS PROGRAM WILL SIMULATE ADDITIONAL VALUES USING ANY
GIVEN JPLP MODEL. IT WILL TAKE AS STARTING CONDITIONS THE LAST VALUES OF A
CE A GIVEN TIME SERIES OR VALUES INPUT BY THE USER. IT UTILIZES THE
JPLP PROGRAM PTGEN.

C3/16/77 15-20-08

FILE: G FAPA P5

NAVAL POSTGRADUATE SCHOOL

GENERATE ---- THIS PROGRAM GENERATES A TIME SERIES SPECIFIED BY THE USER. *02120
IT CAN HANDLE ANY PRIMA MCEFL WITH NUMBER OF AR TERMS. IT POSTMORTEMLY
IF MA TERMS AT MOST 6. THE TIME SERIES CAN BE STATIONARY OR NONSTATIONARY.
SPECIALLY. THE PROGRAM USES FTGFM FROM THE INSL LIBRARY. THE USER
GIVEN MODEL. GENERATES RANDOM NOISE TERMS AND CALCULATES AS MANY VALUES
AS REQUESTED.

PAGE CCI

03/16/77 15.24.00

FILE: ENTER PARA P1

NAVAL POSTGRADUATE SCHOOL

PAGE CCI

THE FIRST TWO CARDS ARE OFFLINE READ CONTROL CARDS:

CPETUSERIC P1P1E WHERE XXXX IS USER ID NUMBER
OFFLINE READ FILE F102FC01

THESE TWO CARDS ARE THEN FOLLOWED BY THE DATA CARDS:

XXX WHERE XXX IS THE LENGTH OF THE TIME SERIES
(NOW ENTER THE TIME SERIES DATA VIA FORMAT DEFERRED)
(USE AS MANY CARDS AS NECESSARY TO ENTER THE TIME SERIES)

SUBMIT THIS DECK WITH NO ADDITIONAL CARDS TO THE OPERATOR TO BE
READ INTO CP/CHS. THEN RETURN FOR ANOTHER SESSION.

LIST OF REFERENCES

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2. Box, G. E.P. and Jenkins, G. M., Time Series Analysis, Forecasting and Control, Holden-Day, San Francisco, 1970.
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